Assessment of Thornyheads (*Sebastolobus sp.*) in the Gulf of Alaska

By

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Summary

This year we updated the model introduced in 1997 with available recent data, including 2001 harvest levels by gear and relative population numbers from the 2002 sablefish longline survey. Alternate models examined assumptions regarding natural mortality and length at age. Results from this year's base model analyses are similar to 2001's, with harvest levels nearly identical for next year under the $F_{40\%}$ fishing mortality.

The following summarizes the (base model) ABC recommendations and status of spawning biomass level for the past few years relative to the current assessment:

Assessment Year	Projection Year	Female spawning biomass	ABC Recommendation
1996	1997	20,331 t	**1,700 t**
1997	1997	22,812 t	
1997	1998	22,778 t	**2,000 t**
1998	1997	23,473 t	
1998	1998	23,483 t	
1998	1999	23,100 t	**1,990 t**
1999	1997	22,809 t	
1999	1998	22,932 t	
1999	1999	23,095 t	
1999	2000	23,084 t	**2,359 t**
2001	1997	22,289 t	
2001	1998	22,521 t	
2001	1999	22,792 t	
2001	2000	22,996 t	
2001	2001	23,150 t	
2001	2002	23,235 t	**2,494 t**
2002	1997	22,579 t	
2002	1998	22,813 t	
2002	1999	23,084 t	
2002	2000	23,286 t	
2002	2001	23,436 t	
2002	2002	23,549 t	
2002	2003	23,567 t	**2,555 t**

Response to SSC comments

The SSC received a report from Sarah Gaichas on the status of stocks of thornyhead rockfish. Model estimates of natural mortality rates seemed high to the SSC in part because they exceed rates for Pacific ocean perch a species with lesser longevity. We suspected that the model might be reacting to a truncated age distribution from the fishery. Thoryhead rockfish are known for their size and age stratification by depth (i.e., their bathymetric demography). For the population along the Pacific coast (WA, OR, CA) smaller fish are typically found on the shelf and larger fish along the slope. We recommend that stock analysts explore the bathymetric demography of the species in Alaskan waters, and evaluate whether the catch-at-age data are appropriately stratified to reflect thornyhead size and age stratification.

This year's assessment explores a new age length key based on radiometric age information, and further explores natural mortality assumptions. We present results from an alternative model that estimates a lower natural mortality rate than the base model presented last year. Fishery catch at size information (there is no catch at age data) is available for trawl fisheries, which account for approximately half of thornyhead catch but tend to take place in shallow depths relative to longline fisheries. As in 2001, length information from the longline fishery was of limited use in examining distribution by depth because less than 40 fish were measured from the fishery in 2002. No new trawl survey information was available this year, and the most recent Gulf of Alaska trawl survey (2001) did not include over half of the habitat thornyheads occupy. Assuming a complete trawl survey of all depths and areas in the Gulf of Alaska takes place in 2003, depth specific length information from all available surveys (including longline surveys) will be examined so that next year's assessment will address bathymetric demography of thornyheads in the Gulf of Alaska.

Introduction

The shortspine thornyhead (*Sebastolobus alascanus*) inhabits deep waters from 92 to 1,460 m from the Bering Sea to Baja California. Thornyheads are abundant throughout the Gulf of Alaska and are commonly taken by bottom trawls and longline gear. In the past, this species was seldom the target of a directed fishery. Today thornyheads are one of the most valuable of the rockfish species, with most of the domestic harvest exported to Japan. The population structure of shortspine thornyheads is not well defined. However, as a matter of practical convenience, thornyheads in the Gulf of Alaska have been managed as a single stock since 1980.

According to Alverson et al. (1964), groundfish species commonly associated with thornyheads include: arrowtooth flounder (*Atheresthes stomias*), Pacific ocean perch (*Sebastes alutus*), sablefish (*Anoplopoma fimbria*), rex sole (*Glyptocephalus zachirus*), Dover sole (*Microstomus pacificus*), shortraker rockfish (*Sebastes borealis*), rougheye rockfish (*Sebastes aleutianus*), and grenadiers (family Macrouridae). Two congeneric thornyhead species, the longspine thornyhead (*Sebastolobus altivelis*) and a species common off Japan, *S. macrochir*, are infrequently encountered in the Gulf of Alaska.

Catch history

As an element of the deepwater community of demersal fishes, thornyheads have been fished in the northeastern Pacific Ocean since the late l9th century, when commercial trawling by U.S. and Canadian fishermen began. In the mid-l960s Soviet fleets arrived in the eastern Gulf of Alaska (Chitwood 1969), where they were soon joined by vessels from Japan and the Republic of Korea.

Thornyhead catches have been reported in a variety of ways. The earliest records available begin in 1967 as published in French et al. (1977). Active data collection began as part of the U.S. Foreign Fisheries Observer Program in l977, when the thornyhead catch in the Gulf of Alaska was estimated at 1,397 t. From l980 on, the observer program has generated annual estimates of the foreign catch of thornyheads by International North Pacific Fisheries Commission (INPFC) statistical area. Since 1983, the observer program has also estimated the catches of thornyheads in the joint venture fisheries. In l984, thornyheads were identified as a separate entity in the U.S. domestic catch statistics.

Estimated thornyhead catches by gear type since 1967 are shown in Table 9.1. Data from 1981 to 1989 are based on reported landings extracted from the Pacific Fishery Information Network (PacFIN) database and the NMFS Observer Program. Before this period, estimates are based on the following reports: French et al. (1977), and Wall et al. (1978-81). Catches in more recent years (1990-1998) are based on "blended" estimates provided by the NMFS Regional Office through the Observer Program. Estimates of discards for these years have been provided as well. The blended and discard estimates are based on a method that makes use of observer data as well as weekly processor reports (WPR). It is interesting to note that for years in which discard information is available, discarding appears to be much more prevalent in the longline fishery than in the trawl fishery. Discards in the domestic fishery before 1990 are unknown. We assumed that the reported catches before 1990 included both retained and discarded catch. Survey research catches of thornyheads (Table 9.2) are a very small component of overall removals.

The catches of thornyheads in the Gulf of Alaska declined markedly in 1984 and 1985 due primarily to restrictions on foreign fisheries imposed by U.S. management policies. The greatest foreign-reported harvest activities for thornyheads in the Gulf of Alaska occurred during the period 1979-83. In 1985, the U.S. catch surpassed the foreign catch for the first time. U.S. catches of thornyheads continued to increase, reaching a peak in 1989 with a total removal of 3,080 t. Catches have since averaged about 1,260 t during the five-year period from 1996 to 2000.

By weight, the directed fishery for sablefish harvested the largest amount of thornyheads in 1999 and 2000, followed by rockfish and the combined flatfish fisheries (Fig. 9.1). In 1999, thornyhead discard from the flatfish fisheries was higher while relatively fewer discards were incurred from the sablefish fishery. Patterns of discard closely matched those of retention for 2000 fisheries. The distribution of thornyhead catches range broadly throughout the Gulf of Alaska and is consistent within recent years for the different gear types (Figs. 9.2 and 9.3).

Table 9.1. Estimated retained catch and discard levels by gear type[1].

	Trawl			Hook and Line			All Gears Combined		
Year	Retained	Discarded	Total	Retained	Discarded	Total	Retained	Discarded	Total
1967	7	-	7	0	-	0	7	-	7
1968	56	-	56	6	-	6	62	-	62
1969	94	-	94	3	-	3	97	-	97
1970	48	-	48	6	-	6	53	-	53
1971	230	-	230	11	-	11	241	-	241
1972	202	-	202	14	-	14	216	-	216
1973	1,550	-	1,550	15	-	15	1,565	-	1,565
1974	1,529	-	1,529	8	-	8	1,537	-	1,537
1975	1,215	-	1,215	15	-	15	1,229	-	1,229
1976	1,189	-	1,189	124	-	124	1,313	-	1,313
1977	1,163	-	1,163	234	-	234	1,397	-	1,397
1978	442	-	442	344	-	344	786	-	786
1979	645	-	645	454	-	454	1,098	-	1,098
1980	1,158	-	1,158	327	-	327	1,485	-	1,485
1981	1,139	-	1,139	201	-	201	1,340	-	1,340
1982	669	-	669	118	-	118	787	-	787
1983	620	-	620	109	-	109	729	-	729
1984	177	-	177	31	-	31	208	-	208
1985	70	-	70	12	-	12	82	-	82
1986	607	-	607	107	-	107	714	-	714
1987	1,863	-	1,863	14	-	14	1,877	-	1,877
1988	2,132	-	2,132	49	-	49	2,181	-	2,181
1989	2,547	-	2,547	69	-	69	2,616	-	2,616
1990	1,233	38	1,271	284	20	304	1,518	58	1,576
1991	1,210	72	1,282	234	497	731	1,444	569	2,013
1992	1,042	114	1,156	534	330	864	1,576	444	2,020
1993	489	173	662	401	305	706	890	478	1,368
1994	493	200	693	309	296	605	802	496	1,298
1995	635	143	778	478	107	585	1,113	250	1,363
1996	578	141	719	475	116	591	1,053	257	1,310
1997	567	224	791	397	61	458	964	285	1,249
1998	470	113	583	508	57	565	978	171	1,148
1999	597	197	794	445	43	488	1,042	240	1,282
2000	557	92	649	580	78	658	1,137	170	1,308
2001	479	52	532	770	38	808	1,249	90	1,339
2002*			791			692			1,482

[1] Prior to 1990 retained catch was assumed to equal retained and discard catch combined. Catches by gear type from 1981-1986 were estimated by apportioning 85% of the total catch to trawl and and 15% to longline gear. ***Source***: 1967-1980 based on estimates extracted from NMFS observer reports (e.g., Wall et al. l978) 1981-1989 based on PACFIN and NMFS observer data, 1990-2001 based on blended NMFS observer data and weekly processor reports. *The 2002 catch was projected from October 2002 NMFS reports.

Table 9.2. Research catches, 1977-2002 in tons.

Year	Domestic Longline Survey Catch	Research catch trawl	Research catch Co-op longline	Total research catch
1977		0.77		0.8
1978		1.20		1.2
1979		4.54	2.93	7.5
1980		1.42	4.98	6.4
1981		9.51	4.64	14.2
1982		5.58	4.11	9.7
1983		0.72	4.22	5.0
1984		23.89	3.10	27.0
1985		12.03	3.51	15.5
1986		1.75	3.50	5.3
1987		16.78	3.54	20.3
1988	1.95	0.04	4.73	6.7
1989	3.44	0.15	4.51	8.1
1990	3.32	3.59	3.64	10.6
1991	3.80		3.38	7.2
1992	5.40		3.72	9.1
1993	4.66	5.49	4.01	14.2
1994	4.41		4.77	9.2
1995	5.42			5.4
1996	6.18	6.05		12.2
1997	5.89			5.9
1998	5.70	9.36		15.1
1999	5.74	23.09		28.8
2000	5.19			5.2
2001	6.72	2.22		8.9
2002	5.43			5.4

Resource Surveys

Longline surveys

Longline surveys have been conducted jointly by the United States and Japan in the Gulf of Alaska each year since 1979 to ascertain the abundance level and length composition of important groundfish species in the depths from 101 to 1,000 m. Since 1987 a U.S. longline survey has also been conducted using similar methodology to the cooperative survey. This survey covered a complete standard area in the Gulf of Alaska beginning in 1990. For each species, the catch rate, the area, and the size composition of samples from each depth stratum were used to determine the relative population number (RPN) and weight (RPW) for each depth stratum. The RPNs and RPWs for the various depth strata (201-1,000 m for thornyheads) were summed to obtain GOA totals (Table 9.3).

Table 9.3. Relative population number (RPN) and weight (RPW) from the domestic longline survey 1990-2002 (Mike Sigler and Chris Lunsford, NMFS Auke Bay Lab, pers. comm.). Note that the RPN data were used to tune the model.

Domestic survey

Year	RPN	RPW
1990	43,479	23,217
1991	56,615	26,618
1992	73,233	35,921
1993	66,166	32,462
1994	49,191	27,766
1995	58,553	28,797
1996	66,392	34,966
1997	62,529	32,128
1998	60,740	33,111
1999	67,901	36,228
2000	59,058	30,588
2001	86,970	45,814
2002	76,996	40,139

The use of the longline survey in general may be questionable because of a possible interaction with sablefish abundance. For example, Sigler and Zenger (1994) found that thornyheads increased in areas where sablefish abundance decreased. They suggested that the increase in thornyhead catch rates between 1988 and 1989 (their data) might be partly due to the decline in sablefish abundance. They reasoned that availability of baited hooks to thornyheads may have increased. Further research is needed on the effect of hook competition between slow, low metabolism species such as shortspine thornyheads and faster, more actively feeding sablefish. The coefficient of variation for the domestic survey index we assumed to be 20%. We present the size compositions from this survey in the section on model fit, below.

The NMFS Auke Bay Lab staff began a feasibility study on tagging shortspine thornyheads from the longline survey in 1997 and have continued to tag shortspine thornyheads on an opportunistic basis in each year including 2001. The methods seem to be working well with minimal interference with normal survey operations. In 2001, 626 shortspine thornyheads were tagged and released bringing the total releases of this species between 1997 and 2001 up to 2,814 individuals. This work is part of an ongoing project to learn more about movement and growth rates of this deep-water species.

Trawl surveys

The most recent NMFS trawl survey for the Gulf of Alaska was conducted during the summer of 2001. This survey employed standard NMFS Poly-Nor'eastern bottom trawl gear and provide biomass estimates using an "area-swept" methodology described in Wakabayashi et al. (1985). The 1984, 1987 and 1999 surveys extended into deeper water (>500 m) and covered the range of primary habitat for the shortspine thornyhead stock. The 2001 survey and surveys during the early 1990s did not extend to the deeper zones where concentrations of larger thornyheads are known to exist. This gives survey biomass estimates a disjointed appearance (Fig. 9.4, upper panel). A comparison of survey biomass estimates by depth strata suggests that different portions of the population are sampled depending on survey depth coverage (Fig. 9.4 lower panel). In addition, the 2001 survey did not extend into the eastern Gulf, where a significant portion of thornyhead biomass has been found in past surveys (Fig. 9.4, lower panel). To account for these differences between surveys, we assume that the 1984, 1987, and 1999 surveys encountered the entire adult population while the 1990, 1993, and 1996 estimates surveyed a smaller portion of the stock. We rescaled the 2001 survey estimate to be equivalent to the 1990–1996 (shallow) surveys by dividing the 2001 estimate from the western and central gulf by the the average proportion of biomass found in the (shallow) western and central gulf in the 1990-1999 surveys. The remaining difference between surveys (deep vs shallow) was accounted for in the model by fixing the catchability coefficient equal to 1.0 for the

1980s and 1999 surveys and allowing separate, freely estimated q value for the 1990–1996 and 2001 surveys. We feel that a significant portion of the biomass of shortspine thornyheads exists beyond depths of 500 m, as illustrated by analysis of longline survey catch-per-unit-effort data (Ianelli and Ito 1994). The ability of our assessment to reflect that actual abundance of shortspine thornyheads is hampered by the lack of reliable data in these deeper habitat areas (and now in the eastern Gulf of Alaska). The spatial distribution of relative thornyhead catch rates observed in the triennial surveys from 1984-1999 suggests lower densities in 1990 and 1993 compared to other years, particularly in the western area (Fig. 9.5). For comparison, the 2001 survey cpue is included.

Analytic approach

In 1997 a sized based, age-structured model was developed and applied to the thornyhead resource in the Gulf of Alaska. In 1998, the original model was re-written in C++ computer language in order to take advantage of analytical software designed for building large, complex models. We use essentially the same model in this assessment, with additional exploration of natural mortality and length at age assumptions.

The conceptual model is similar to that commonly implemented in the stock synthesis program (Methot 1990). Catch data were from 1967 to 2002 with the last twelve years adjusted to include discards. Before this time we assumed harvests of the resource was negligible. Model parameters are estimated by maximizing the log likelihood (L) of the predicted observations given the data. Data are classified into different components. For example, size compositions from a survey and from a fishery represent different components. The total L is a sum of the likelihoods for each component. The total L may also include a component for a stock-recruitment relationship. The likelihood components may be weighted by an emphasis factor. For shortspine thornyheads in the GOA, the model was aggregated to have two fisheries and included the NMFS triennial trawl surveys and the NMFS domestic longline survey. Table 9.4 summarizes the data types used in this assessment. Table 9.5 presents the key equations used for the shortspine thornyheads model in the Gulf of Alaska and a description of key variables is given in Table 9.6. Statistical formulae for the likelihood components are given in Table 9.7.

Table 9.4. Data types used in the model for shortspine thornyheads in the GOA.

Data Component	**Years of data**
Trawl survey size composition and biomass estimates	1984, 1987, 1990, 1993, 1996, 1999, 2001
Longline survey relative abundance and size composition	1990-2002
Trawl fishery size composition data	1976-77, 1982-84, 1990-96, 1998-2002
Longline fishery size composition data	1977-81, 1991-95, 1998, 2000-2002
Trawl fishery harvests	1967-2002
Longline fishery harvests	1967-2002

Table 9.5. Model equations describing population dynamics.

Equations	Description
$N_{t,1} = R_t = R_0 e^{\tau_t}$, $\tau_t \sim \mathrm{N}\left(0,\sigma_R^2\right)$	Recruitment
$C_{i,t,a} = \dfrac{F_{i,t,a}}{Z_{t,a}}\left(1-e^{-Z_{t,a}}\right) \quad N_{t,a} \quad 1 \le t \le T \quad 1 \le a \le A$	Catch gear type *i*, year *t*, age class *a* Numbers
$N_{t+1,a+1} = N_{t,a} e^{-Z_{t,a}} \quad 1 < t \le T \quad 1 \le a < A$	
$S_t = \sum_{a=5}^{54+} w_{t,a} \phi_a N_{t,a}$	Spawning biomass in year *t*
$N_{t+1,A} = N_{t,A-1} e^{-Z_{t,A-1}} + N_{t,A} e^{-Z_{t,A}} \quad 1 \le t \le T$	Numbers in "plus" group"
$Z_{t,a} = \sum_i F_{i,t,a} + M$	Total Mortality
$F_{i,t,a} = s_{i,a} \mu_i^F \exp\left(\varepsilon_{i,t}\right) \quad \varepsilon_{i,t} \sim N\left(0,\sigma_i^2\right)$	Components of fishing mortality
$s_{i,a} = \exp\left(\eta_{i,a}\right) \quad \eta_{i,a} \sim N\left(0,\sigma_{s_{i,a}}^2\right)$	Age-effect of fishing
$C_{t\cdot}^i = \sum_{a=1}^{A} C_{t,a}^i$	Total catch for fishery *i*.
$p_{t,a}^i = \dfrac{C_{t,a}^i}{C_{t\cdot}^i}$	Proportion at age in catch
$\hat{Y}_t^i = \sum_{a=1}^{A} w_{t,a} C_{t,a}^i$	Yield in year *t* for fishery *i*.
X	Transition matrix dimensioned by 50 ages by 25 length bins (*L*), parameterized by growth relationship shown in Figure 6.
$\hat{g}_t^i = p_t^i \cdot X,\ \hat{g}_{t,l}^i,\ l = 1,2,3...L$	Proportion at length in vector $\hat{g}_t^i$ for fishery or survey *i* in year *t*.

Table 9.6. List of variables and their definitions used in this model.

Variable	Definition
R_t	age 1 recruitment in year *t*
R_0	geometric mean value of age 1 recruitment, 1967-2002
$R_0^{'}$	geometric mean value of age 1 recruitment prior to 1967 (establishes initial age composition)
τ_t	recruitment deviation in year *t*
T	number of years of fishing (i.e., *t*=1 corresponds to 1967, and *t*=*T* corresponds to 2002)
A	number of age classes in the population model (*A*=50 ranging from *a*=1 that corresponds to age 5 and *a*=50 corresponds to fish age 54 and older,
$N_{t,a}$	number of fish age *a* in year *t,*
$C_{t,a}$	catch number of age group *a* in year *t,*
$P_{t,a}$	proportion of the total catch in year *t,* that is in age group *a,*
$C_{t\cdot}$	total catch in year *t,*
$W_{t,a}$	mean body weight (kg) of fish in age group *a* in year *t,*
θ_a	proportion mature at age *a*, $\theta_a = \dfrac{1}{1+e^{-(\rho a-\beta)}}$
Y_t^i, $\hat{Y}_t^i$	total yield weight in year *t,* fishery *i,* observed and estimated.
$F_{i,t,a}$	instantantaneous fishing mortality for gear type *i,* age group *a,* in year *t,*
M	instantantaneous natural mortality (assumed constant for all ages and years,
$Z_{t,a}$	instantantaneous total mortality for age group *a,* in year *t,*
$S_{i,a}$	age-effect of fishing for age group *a* in gear type *i,* normalized to average 1.0 over ages *a*=1 to *A*,
μ_i^F	median year-effect of fishing mortality,
$\varepsilon_{i,t}$	the residual year-effect of fishing mortality (note that effective effort fluctuates in fidelity to the total catch each year).

Table 9.7. Statistical formulae for the likelihood components.

Equations	Description
$L_1 = \sum_f \sum_t n_t^f \sum_{l=1}^{L} \ln\left(\hat{g}_{t,l}^f\right)$	Multinomial –log likelihood value for *f* observation types (fisheries and surveys)
$L_2 = \sum_i \sum_{t_i} \dfrac{\ln\left(I_{t_i}^i / \hat{I}_{t_i}^i\right)^2}{2\left(\sigma_{t_i}^i\right)^2}$	Likelihood component for indices *ith* abundance index (i.e., bottom trawl and longline surveys)
$L_3 = \lambda_1 \sum_{i,t} \varepsilon_{i,t}^2$	Fishing mortality term for each *i* fishery (provides regularity,
$L_4 = \lambda_2 \sum_{i,t} \left(Y_t^i - \hat{Y}_t^i\right)^2$	Catch biomass component
$L_5 = \lambda_3 \ln\left(\hat{M} / M_{prior}\right)^2 + \lambda_4 \ln\left(\hat{q} / q_{prior}\right)^2$	Prior components on natural mortality, and survey catchability.
$L_6 = \sum_{i,a} \dfrac{\left(\eta_{i,a}\right)^2}{2\sigma_{s_{i,a}}^2}$	Component constraining age-age variability in selectivity for each *i* gear type.
$L_{tot} = \sum_{i=1}^{6} L_i$	Total – log likelihood (or posterior pdf)

Parameters estimated independently

Miller (1985) estimated thornyhead natural mortality by the Ricker (1975) procedure to be 0.07. The oldest thornyhead she found was 62 years old. On the U.S. continental west coast, at least one large individual was estimated to have a maximum age of about 150 years old (Jacobson 1990). Another study of west coast thornyheads found a 115 year old individual using conventional ageing methods (Kline

1996). These maximum ages would suggest natural mortality rates ranging from 0.027 to 0.036 if we apply the relationship developed by Hoenig (1983). Recent radiometric analyses suggest that the maximum age is between 50-100 years (Kastelle et al 2000, Cailliet et al 2001), but these are high-variance estimates due to sample pooling and other methodological issues. A recent analysis of reproductive information for Alaska and west coast populations also indicates that shortspine thornyheads are very long-lived (Pearson and Gunderson, in review). The longevity estimate was based on an empirically derived relationship between gonadosomatic index (GSI) and natural mortality (Gunderson 1997), and suggested much lower natural mortality rates (0.013-0.016) and therefore much higher maximum ages (250-350 years) than had ever been previously reported using any direct ageing method. In past assessments, we attempted to estimate growth within a size-based model using some assumptions from Miller (1985). Here we examine other assumptions about natural mortality and length at age for comparison with the base model, because considerable uncertainty surrounds age and growth parameters for shortspine thornyheads.

In the base model, we use the same age and growth assumptions as in the 1999 assessment by specifying that a 5-year old shortspine thornyhead has a mean size of 15 cm and a 54-year old fish has a mean length of 51 cm. The von-Bertalanfy growth parameter used to "bridge" these mean lengths, *k,* was assumed to be 0.022 based on estimates from past assessments. We selected coefficients of variation in length at age to be 9% at age 5 and 8% at age 54 (based on experience with variability in length-at-age with other rockfish; e.g., Pacific ocean perch). These values were used to create the transition matrix that the model used to convert between modeled numbers-at-age to observed proportions at size.

New length weight information collected during the 1999 Gulf of Alaska trawl survey was used in this assessment. The following length weight parameters were estimated using the nonlinear least squares (nls) function in S-Plus 5 to relate weights and lengths measured for 945 fish:

$$\text{weight (kg)} = a(\text{fork-length(cm)})^b$$
$$a = 3.3549\text{x}10^{-6}, \quad b = 3.3486$$

As in the previous assessment, we chose the size-at-maturity schedule estimated in Ianelli and Ito (1995) for shortspine thornyheads off the coast of Oregon. In this ogive, female shortspine thornyheads appear to be 50% mature at about 22 cm or about 11 years old (Fig. 9.6 top panel). More recent data analyzed in Pearson and Gunderson (in review) estimated length at maturity for Alaska fish at 21.5 cm (although length at maturity for west coast fish was revised downward to about 18 cm). Therefore, we maintained the assumption of a 22 cm length at maturity. These length weight and maturity parameters were unchanged in alternative models.

As presented in last year's assessment, we use the base model to evaluate uncertainties in the estimate of natural mortality (M) by selecting a prior distribution rather than assuming a fixed value. Initial model runs using a moderately diffuse (uninformative) prior distribution about M indicated that the best fit was attained with a relatively high value of M (given constraints placed on declining selectivity with age). Therefore, we selected a relatively informative prior on M with an expected value of 0.05 and a coefficient of variation equal to 10% (Fig. 9.7). This resulted in an estimate (0.08) similar to the fixed value assumed in 1998 (0.07) but still allowed for some accounting of uncertainty in this parameter.

Last year we developed two alternative models to examine different assumptions about natural mortality (M). In both, natural mortality rates were fixed at a previously defined value, rather than estimated from the data and a prior distribution as in the base model. In the first model, natural mortality was fixed at 0.0129, the value estimated in Pearson and Gunderson (in review) by the GSI regression method for thornyheads in reproductive development stage 5. In the second model natural mortality was fixed at 0.038, an alternative value from the same study. For comparison, all other aspects of the model configuration were kept the same as in the base run. In alternate runs, added constraints on selectivity were included.

This year we retain the model run with M fixed at 0.038, primarily because the Plan Team recommended that ABC be based on that model last year, and the SSC concurred. (We note, however, that Pearson and

Gunderson argue that the GSI regression relationships give better support to the lower estimate of M, 0.0129.) The model runs examining *M* assumptions are named "FixM 0.038" for the model that only set *M*, and "FixM 0.038 Sel," for the model that constrained selectivity simultaneously.

Last year, two additional model runs examined alternative length at age relationships. One was based on a recent study by Kline (1996) on west coast thornyheads which used both conventional and radiometric methods to age a relatively large number of fish. With 353 fish, Kline estimated the von Bertalanffy growth parameters Linf = 94.5 cm, k = 0.017, and t0 = -5.52. These parameters were used to generate an age length transition matrix with the same assumptions about variation in length at age (cv of 9% for younger and 8% for older fish) as given above. All of the fish used in this study were collected on the west coast south of Santa Cruz, CA. There may be differences in growth between west coast and Alaska thornyheads (as was found for length at maturity by Pearson and Gunderson in review), so we also constructed a second model based on length at age information collected by Kastelle (2000) specific to Gulf of Alaska thornyheads. The disadvantage of Kastelle's data is that the study was less extensive than Kline's and did not include fitting a von Bertalannfy growth function. Therefore, we used the mean length at age for small (average age 5.5, mean length 14 cm, n=45) and large (median age 36, mean length 37 cm, n=41) fish and the *k* parameter estimated by Kline (0.017) to formulate a growth curve. These alternative model runs with different age length transition matrices did not substantially alter the results relative to the base model. Neither model fit the observed length composition data better than the base model, and individual likelihood components appear to trade off improved fits to survey indices with less likely estimates of natural mortality. There is no indication that either of these age length relationships is better than the one in the base model, so we don't re-examine them this year.

This year yet another alternative length at age relationship was constructed based on radiometric age information from Kastelle et al (2000), and length at maturity information from the Pearson and Gunderson study. We assumed that the age at maturity estimated from radiometric data (23.5 years, table 7 in Kastelle et al 2000) would coincide with the length at maturity determined histologically (22 cm). Therefore, the von-Bertalanfy curve was forced though this point by using the t0 and Linf parameters estimated for the Kastelle radiometric data above and adjusting the k parameter. The final "growth" parameters for this model were Linf = 70 cm, k = 0.012, and t0 = -8, and the age length transition matrix was constructed using the same assumptions about variation in length at age as in all other models. All length at age relationships are shown in Figure 9.6. Model runs with this age length transition matrix also included an adjusted length at maturity and weight at age relationship to reflect the length at age assumptions; all other model assumptions including selectivity and priors on M were identical to the base model. Results from this alternative model are presented as "Radiometric AgeLength."

Results/Model evaluation

Comparing among these models (Table 9.8), it appears that the available data do not support the low GSI-based estimates of natural mortality (given the other assumptions of the model), nor do they support the radiometric-based age length relationship. With low natural mortality rates specified, the estimates of fishing mortality rates decreased, as did selectivity of older fish in both gear types and longline survey catchability. Fixing *M* to these low values resulted in considerably poorer fits relative to the base model. As expected, low specified values for *M* resulted in a consistent mode of large fish in both survey and fishery size compositions. This is inconsistent with what has been observed. Model runs with strong constraints against dome-shaped selectivity ("FixM 0.038Sel") resulted in lower biomass and yield estimates, still with poor fits to observed size compositions and poor likelihoods. These models predict increasing biomass trends over time, presumably because the old fish do not die off and are not caught in fisheries (or surveys). We note that the predicted yields from the alternative models exceed recent thornyhead catches in the Gulf of Alaska, so if these results were used as a basis for ABC, the effects on the fishery would be minor.

Table 9.8. Alternative model results for shortspine thornyheads in the Gulf of Alaska; effective sample size and likelihood components. See text for model descriptions.

Description	Base model	FixM 0.038	FixM 0.038 Sel	Radiometric AgeLength
Effective N				
Trawl Fishery	170	83	66	57
Longline Fishery	54	40	39	32
Trawl survey	316	359	262	74
Longline survey	316	93	89	82
Likelihoods				
Surveys				
Trawl Survey	44.3	49.0	57.0	58.4
Longline Survey	9.6	7.5	6.4	16.1
Priors				
Prior on M	22.9	0.0	0.0	9.0
Recruitment Likelihood	18.5	55.8	87.3	16.7
Trawl Fishery Size comp	64.7	84.8	96.2	74.4
Longline Fishery Size comp	84.4	89.2	90.6	206.8
Trawl Survey Size comp	19.6	22.2	36.4	41.4
Longline Survey Size comp	24.4	51.9	53.6	212.2
Trawl Fishery selectivity	1.9	3.1	1.1	1.2
Longline Fishery selectivity	0.7	3.9	1.2	2.5
Trawl Survey selectivity	4.8	8.9	11.5	14.6
Longline Survey selectivity	3.6	19.2	3.9	6.5
Catch likelihood	0.1	0.1	0.1	0.1
Total Likelihood	299.5	395.6	445.3	660.0

Table 9.8 cont'd. Alternative model results for shortspine thornyheads in the Gulf of Alaska; estimates of biomass (current, B40% and pristine), recruitment, yield, and fishing mortality rates. See text for model descriptions.

Description	Base model	FixM 0.038	FixM 0.038 Sel	Radiometric AgeLength
2002 Biomass	53,690	85,758	69,808	60,110
(cv)	7%	7%	6%	7%
$B_{40\%}$	35,594	75,896	67,680	35,608
(cv)	10%	7%	7%	11%
B0	89,851	189,950	169,390	89,104
(cv)	10%	7%	7%	11%
2002 Biomass / $B_{40\%}$	151%	113%	103%	169%
2002 Biomass / B0	60%	45%	41%	67%
Average age 5 recruitment (all years)	22,730	10,312	9,597	18,109
Average age 5 recruitment (since 1977 spawning)	25,121	10,748	9,646	17,921
Natural Mortality	0.081	0.038	0.038	0.037
Yield				
2002 Yield $F_{40\%}$	2,555	1,998	1,759	1,675
2002 Yield $F_{35\%}$	3,051	2,344	2,081	2,009
Full selection F's				
Trawl $F_{40\%}$	0.039	0.019	0.015	0.021
Longline $F_{40\%}$	0.046	0.017	0.015	0.021
$F_{40\%}$ Combined	0.085	0.036	0.030	0.042
Trawl $F_{35\%}$	0.047	0.023	0.018	0.025
Longline $F_{35\%}$	0.056	0.020	0.018	0.026
$F_{35\%}$ Combined	0.102	0.042	0.035	0.051

While the total likelihoods and effective Ns indicate poorer support of the data for the three alternative models than for the base model, it is interesting that the natural mortality rate estimated by the Radiometric AgeLength model, 0.037, is very close to at least one M estimated by the GSI method (albiet the weaker estimate). We also note that some of the data, in particular the longline fishery size composition data which is plagued by extremely low sampling, may not be worth supporting. Next year when we assume data from a full trawl survey of the Gulf of Alaska including all depths and regions will be available, we plan to further investigate bathymetric demography of thornyheads from all of surveys in order to evaluate how length data from fisheries might be better accommodated. The length at age relationship for thornyheads in the Gulf of Alaska is still highly uncertain, which will always be a problem for this assessment until further work on age and growth is completed.

Because the discussion, tables and figures from the base model configuration this year look astoundingly similar to those from the last year's base model, we refer the reader to last year's assessment to see what they looked like. To make life interesting, subsequent discussion, figures and tables reflect results from the Radiometric AgeLength model configuration (the model with the worst statistical fit which results in the lowest ABC recommendation, but estimates similar reference points to the base model). We feel this will provide new insight for the Plan Team.

The fits to the observed size composition data for these results were adequate for some years and not so reasonable for others (Fig. 9.8), and the fit to the abundance indices was not particularly good, but not remarkably worse than for the base model (Fig. 9.9). The trawl survey abundance index was within the observed confidence bounds (see Fig. 9.4). Like the base model, the Radiometric AgeLength model does not capture what might be an increasing trend in the longline survey data. The problem remains that the observations do not provide information to suggest whether strong year-classes have occurred. This is due, in part, to the fact that the distribution of thornyheads is widespread and relatively homogenous (i.e., they do not form highly aggregated schools) and because the sample size on length frequency from the fisheries is low. In addition, the ability to obtain a reasonable progression of length modes may be inherently problematic given the slow and perhaps erratic growth of these fish. A sensitivity analyses on the emphasis placed on fitting the longline survey abundance index shows that the overall model fit significantly degrades with increasing longline survey index emphasis (Ianelli and Ito, 1995). Selectivity estimates for the surveys and fisheries are shown in Fig. 9.10.

Abundance and exploitation trends

Results from the Radiometric AgeLength model show that the abundance of shortspine thornyheads has decreased slowly since 1970 (Table 9.9, Fig. 9.11). Fishing mortality rates peaked at about 0.03 in 1989 while for recent years, the rate has remained around 0.01 (Fig. 9.12).

Table 9.9. Estimates of beginning of year 5+ biomass, female spawning biomass, and recruitment for shortspine thornyheads in the Gulf of Alaska, Radiometric AgeLength model.

Year	Total age 5+ Biomass	Female Spawning Biomass	Age 5 Recruitment
1967	85,766	38,642	10,187
1968	86,080	38,909	10,657
1969	86,313	39,142	11,452
1970	86,491	39,348	12,676
1971	86,696	39,566	14,003
1972	86,701	39,679	16,072
1973	86,734	39,789	18,877
1974	85,414	39,217	22,644
1975	84,143	38,637	25,235
1976	83,192	38,184	25,329
1977	82,155	37,663	23,855
1978	81,036	37,076	22,602
1979	80,542	36,766	21,380
1980	79,736	36,279	20,396
1981	78,551	35,586	20,242
1982	77,530	34,952	20,141
1983	77,085	34,581	20,172
1984	76,713	34,235	19,985
1985	76,880	34,147	19,695
1986	77,180	34,127	18,941
1987	76,843	33,811	18,202
1988	75,338	32,952	17,870
1989	73,548	31,980	17,799
1990	71,339	30,837	17,896
1991	70,210	30,236	18,015
1992	68,679	29,459	19,151
1993	67,155	28,710	17,152
1994	66,309	28,307	17,213
1995	65,554	27,964	17,157
1996	64,751	27,610	16,661
1997	64,022	27,296	16,675
1998	63,371	27,027	16,633
1999	62,844	26,814	16,685
2000	62,200	26,547	16,657
2001	61,552	26,271	16,800
2002	60,894	25,985	16,832

Recruitment

Results from the present study confirm Miller's (1985) suggestion that year class success is variable for shortspine thornyheads in the GOA. Several strong year-classes were apparent but the ability to resolve the precise recruitment year was poor. This is because the thornyheads appear to grow very slowly and have a variable size-at-age relationship that can mask signals of strong year-classes. A plot of the estimated stock and recruitment is very uninformative because of the lack of contrast in spawning biomass levels over the period for which estimates were available (Fig. 9.13).

Projected catch and abundance

Thornyhead exploitable biomass projected to the year 2015, assuming average recruitment of 5 year olds, shows a slow decline when fished at the $F_{40\%}$ rate (Fig. 9.14). Similarly, yields show a slow short-term decline at the $F_{40\%}$ rate (Fig. 9.15). The average recruitment was computed from the period 1967-2001. Although guidelines suggest using recruitment from spawning that occurred from 1977 and later for projecting catch and biomass, we were compelled to use the entire stock assessment period for the following reasons. The model uses 50 age classes and hence responds slowly to variability in recruitment. The time scales of environmental change and harvest projection periods are relatively small.

Also, since we examined constant-recruitment scenarios last year as plausible alternatives given available data, the impact of using the entire time series is likely to be minor.

Maximum sustainable yield (MSY) calculations require assumptions about the stock recruitment relationship, which for shortspine thornyheads may be impractical as many functional forms can fit the data equally well. As presented above, the $F_{40\%}$ harvest strategy was selected in the absence of information on the stock-recruitment productivity relationship required for calculating MSY levels.

Reference fishing mortality rates and yields

This assessment uses a time-series of data from several different sources and attempts to provide a comprehensive view of the status of the fishery as well as its history. The values for average fishing mortality and yields are given in Table 9.10 with the historical estimates given in Table 9.11.

Since management of thornyheads is not specific to different types of fishing gear, (i.e., there are no direct allocations of the TAC) the fraction of the TAC harvest by trawl versus longline gear is unpredictable. For our recommendations, we assume that the relative proportions of the SPR (spawning-biomass per recruit) fishing mortality rate in the next year will be similar to the value estimated for 2002. Previously (Ianelli *et al.* 1997) we showed that since the SPR rates are a function of gear selectivity, and the selectivity between trawl and longline gear is quite different, not knowing the relative harvests between gears can be misleading for deriving an SPR rate. For example, longline gear tends to harvest the older segment of the stock, consequently, they are able to harvest at a higher rate and still maintain reasonable spawning stock reserves. Also, please note that we assume that spawning occurs during the month of April (Ianelli *et al.* 1994).

We attempt to present an alternative way to summarize the uncertainty in our yield recommendations. Typically, we estimate the SPR fishing mortality rate (e.g., $F_{40\%}$) by using the fixed assumed (or estimated) values of natural mortality, growth, and fishery selectivity. We then apply this rate to a single (or series of) point estimate(s) of projected stock size to compute the ABC value. This year we devised a method of doing these computations within the estimation framework, thereby enabling us to carry through measures of uncertainty in yield estimates. Without going into detail, this technique involves using the Delta method, also referred to as propogation-of-error. This method presents the uncertainty of *functions* that involve random variables. For example, how does current stock size vary if natural mortality is treated as a random variable? In addition, how do these uncertain quantities affect estimates of yield under the $F_{40\%}$ harvest rate? The result from this application is shown in Figure 9.16. The vertical axis of this figure represents the cumulative odds that the “true” yield at a given SPR rate is less than the value on the horizontal axis. For example, following the $F_{40\%}$ curve along until the horizontal axis reads 1,579 tons gives a vertical scale of 25%. This implies that there is (approximately) a 25% chance that the “true” yield at the $F_{40\%}$ harvest rate is *less* than 1,579 tons. Interestingly, the “point” estimate of 1,675 tons under the $F_{40\%}$ level coincides with a very minute probability (~3% chance) that the overfishing level ($F_{35\%}$) would be exceeded. This framework can also be used to reflect the uncertainty in future catch by different gear types.

Table 9.10. Reference fishing mortality rates (coefficient of variation in parenthesis), and yield for 2003 with upper and lower 25 percentiles for ABC and OFL computations, Radiometric AgeLength model. Fishing mortality rates expressed as full selection values.

	Longline	Trawl	Combined
$F_{40\%}$	0.021	0.021	0.042
	(8%)	(6%)	
$F_{35\%}$	0.026	0.025	0.051
	(8%)	(6%)	
	25%	**50%**	**75%**
ABC	1579	**1675**	1776
OFL	1896	2009	2128

*Assuming relative catch in 2002 is the same between the gear types.

Table 9.11. Radiometric AgeLength Model estimates of the trend in average (ages 5-54) and full selection fishing mortality rates by gear type and combined for shortspine thornyheads in the Gulf of Alaska.

	Average F			Full selection F		
Year	**Trawl**	**Longline**	**Combined**	**Trawl**	**Longline**	**Combined**
1967	0.000	0.000	0.000	0.000	0.000	0.000
1968	0.001	0.000	0.001	0.001	0.000	0.001
1969	0.001	0.000	0.001	0.002	0.000	0.002
1970	0.000	0.000	0.000	0.001	0.000	0.001
1971	0.002	0.000	0.002	0.004	0.000	0.004
1972	0.002	0.000	0.002	0.003	0.000	0.003
1973	0.014	0.000	0.014	0.025	0.000	0.025
1974	0.014	0.000	0.014	0.025	0.000	0.025
1975	0.011	0.000	0.011	0.020	0.000	0.020
1976	0.011	0.001	0.012	0.020	0.002	0.022
1977	0.011	0.002	0.013	0.020	0.004	0.023
1978	0.004	0.002	0.007	0.008	0.005	0.013
1979	0.006	0.003	0.009	0.011	0.007	0.018
1980	0.011	0.002	0.014	0.020	0.005	0.026
1981	0.011	0.001	0.013	0.020	0.003	0.024
1982	0.007	0.001	0.008	0.012	0.002	0.014
1983	0.006	0.001	0.007	0.011	0.002	0.013
1984	0.002	0.000	0.002	0.003	0.001	0.004
1985	0.001	0.000	0.001	0.001	0.000	0.002
1986	0.006	0.001	0.007	0.011	0.002	0.013
1987	0.020	0.000	0.020	0.036	0.000	0.036
1988	0.023	0.000	0.023	0.042	0.001	0.043
1989	0.029	0.001	0.029	0.052	0.001	0.053
1990	0.015	0.003	0.017	0.026	0.006	0.032
1991	0.015	0.006	0.021	0.027	0.014	0.041
1992	0.014	0.008	0.022	0.025	0.017	0.042
1993	0.008	0.007	0.015	0.015	0.015	0.029
1994	0.009	0.006	0.014	0.016	0.013	0.028
1995	0.010	0.006	0.016	0.018	0.013	0.030
1996	0.009	0.006	0.015	0.016	0.013	0.030
1997	0.010	0.005	0.015	0.018	0.011	0.029
1998	0.007	0.006	0.014	0.014	0.013	0.027
1999	0.010	0.005	0.016	0.019	0.012	0.030
2000	0.008	0.007	0.016	0.015	0.016	0.031
2001	0.007	0.009	0.016	0.013	0.020	0.033
2002	0.011	0.008	0.018	0.019	0.018	0.037

Acceptable biological catch

Results from the Radiometric AgeLength model were shown for information purposes, but we have difficulty recommending harvest levels based on the model with the worst fit to the data. Therefore, all recommendations and projections come from the base model, which explains the data best at the cost of an unpalatable estimate of M. The recommended 2003 $F_{40\%}$ harvest level (corresponding to full selection

F=0.085) for shortspine thornyheads in the GOA is **2,555 t**. This is slightly increased compared to last years's $F_{40\%}$ rate based harvest of 2,494 t. The long-term expected value of female spawning biomass with fishing held at $F_{40\%}$, referred to as the $B_{40\%}$ level, is estimated at about **16,045** t. This is substantially lower than the current estimate of female spawning biomass of **23,549** t. Therefore, under the ABC and overfishing definitions (Plan Amendment 56), no adjustment to the $F_{40\%}$ harvest rate is required.

Overfishing level

The Council's overfishing definition is the fishing mortality rate which reduces the spawning biomass per recruit to 35% of its pristine level. For shortspine thornyheads in the Gulf of Alaska that value (averaged over all ages) corresponds to F=0.102 (full selection). This rate corresponds to a catch level of **3,051 t** in 2003, assuming equal catches by gear type.

Standard harvest scenarios and projections

This year, a standard set of projections is required for each stock managed under Tiers 1, 2, or 3 of Amendment 56. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Policy Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with the vector of 2002 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2003 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2002. In each subsequent year, the fishing mortality rate is determined based on the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2003, are as follow ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

Scenario 1: In all future years, F is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)

Scenario 2: In all future years, F is set equal to a constant fraction of max FABC, where this fraction is equal to the ratio of the FABC value for 2002 recommended in the assessment to the max FABC for 2002. (Rationale: When FABC is set at a value below max FABC, it is often set at the value recommended in the stock assessment.)

Scenario 3: In all future years, F is set equal to 50% of max FABC. (Rationale: This scenario provides a likely lower bound on FABC that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)

Scenario 4: In all future years, F is set equal to the 1998-2002 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of FTAC than FABC.)

Scenario 5: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Scenarios 1 through 5 were projected 5 years from 2002 (Table 9.12).

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follow (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

Scenario 6: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be above ½ of its MSY level in 2002 and above its MSY level in 2013 under this scenario, then the stock is not overfished.)

Scenario 7: In 2002 and 2003, F is set equal to *max* F_{ABC}, and in all subsequent years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2015 under this scenario, then the stock is not approaching an overfished condition.)

Scenarios 6 and 7 were projected 13 years from 2002 using base model output (Figure 9.17). Under scenario 6, mean biomass projected for 2003 (22,360 t) is greater than ½$B_{35\%}$ (7,341 t), and mean biomass projected for 2012 (17,106 t) is greater than $B_{35\%}$ (14,681 t). Under scenario 7, mean biomass projected for 2014 (16,835 t) is also greater than $B_{35\%}$. These projections indicate that GOA thornyheads are not currently below MSST, and are not expected to approach MSST status in the next two years.

Table 9.12. Projected biomass and catch under five harvest scenarios.

Reference Points (all biomass estimates refer to female spawners)							
	B_0	39,566					
	$B_{40\%}$	15,826					
	$B_{35\%}$	13,848					
	Year	2002	2003	2004	2005	2006	2007
Scenario							
1: Max ABC							
	Mean Biomass	22,893	22,782	22,306	21,821	21,332	20,857
	Stdev Biomass	0.00	3.83	10.31	19.31	33.35	55.50
	Mean Catch	1,500	2,462	2,440	2,413	2,377	2,333
	Stdev Catch	0.00	0.90	1.33	1.73	2.22	2.86
2: 65% max ABC							
	Mean Biomass	22,893	22,890	22,824	22,727	22,604	22,471
	Stdev Biomass	0.00	3.83	10.33	19.40	33.55	55.97
	Mean Catch	1,500	1,617	1,635	1,650	1,657	1,657
	Stdev Catch	0.00	0.59	0.87	1.13	1.45	1.87
3: 50% max ABC							
	Mean Biomass	22,893	22,936	23,050	23,129	23,177	23,208
	Stdev Biomass	0.00	3.83	10.34	19.43	33.65	56.17
	Mean Catch	1,500	1,249	1,275	1,297	1,314	1,324
	Stdev Catch	0.00	0.45	0.67	0.87	1.12	1.45
4: 5 Year average F (=0.03)							
	Mean Biomass	22,893	22,918	22,960	22,969	22,948	22,913
	Stdev Biomass	0.00	3.83	10.34	19.42	33.61	56.09
	Mean Catch	1,500	1,395	1,418	1,438	1,452	1,459
	Stdev Catch	0.00	0.51	0.75	0.97	1.25	1.61
5: No catch							
	Mean Biomass	22,893	23,091	23,821	24,529	25,212	25,880
	Stdev Biomass	0.00	3.83	10.38	19.56	33.95	56.85
	Mean Catch	1,500	0	0	0	0	0
	Stdev Catch	0.00	0.00	0.00	0.00	0.00	0.00

Other considerations

Currently thornyheads are managed for the entire Gulf of Alaska. Based on the 1999 survey estimate that sampled in deeper strata than the other 1990s surveys, we computed the following apportionment of shortspine thornyheads ABC broken out by management areas compared to past years survey estimates as follows:

Biomass (tons)					
	Year	**Western**	**Central**	**Eastern**	**Total**
	1990	1,679	5,941	11,997	19,617
	1993	3,706	12,509	16,808	33,023
	1996	8,043	18,741	24,912	51,696
	1999	14,090	32,593	30,671	77,353
Proportion		**Western**	**Central**	**Eastern**	
	1990	9%	30%	61%	
	1993	11%	38%	51%	
	1996	16%	36%	48%	
	1999	18%	42%	40%	
		Western	**Central**	**Eastern**	**Total**
		18%	42%	40%	
	ABC	460	1,073	1,022	**2,555**

Because the 2001 trawl survey covered only the western and central Gulf of Alaska, and did not cover deeper waters even in these regions, we will not be using information from that survey to recommend apportionment of shortspine thornyhead ABC by management area.

Historical removals by foreign vessels appear to have been more concentrated in the central region (Ianelli and Ito, 1995). Since this pattern may reflect current trends, we recommend that management of thornyheads be broken into these regions rather than Gulf-wide. Presently it is impossible to determine the relative magnitude of thornyhead removals in these areas since observer coverage is not evenly distributed. Further considerations on future harvest levels must also account for the impact of trawl closure areas in the eastern portion of the GOA. The impact of this closure will likely shift the relative proportion caught by gear type, but since this will increase the proportion caught by longline gear, the harvest levels recommended here are likely to be more conservative than if the pressumed shift in catch by gear type was accepted.

Summary

The management parameters of interest derived from this assessment are presented in Table 9.13. Please note, however, that management actions should be based on a more complete evaluation of the alternatives presented above rather than the single values given here.

Table 9.13. Summary management values based on this 2002 assessment for shortspine thornyheads in the Gulf of Alaska.

Management Parameter	**Value**
M (natural mortality)	0.0806 yr^{-1}
Approximate age at full recruitment	Younger for trawl, older for longline
$F_{35\%}$ (Full selection)	0.102
$F_{40\%}$ (Full selection)	0.085
Unfished female spawning biomass	35,735 t
Long-term $B_{40\%}$ (female spawning biomass)	16,044 t
2002 female spawning biomass	23,235 t
2002 age 5+ biomass	53,549 t
F_{ABC}	0.085
ABC (Reference model)	**2,555 t**
$F_{overfishing}$	0.102
Overfishing level	**3,051 t**

Acknowledgments

We thank Nancy Maloney for providing information and support for the shortspine thornyheads tag release-recapture database. Mike Sigler provided updates for the longline survey data. Michael Martin provided the 1999 NMFS survey data and from past years as well. Thanks also to the entire participating RACE Division staff for surveying deep-water stations in 1999.

References

Alverson, D. L., A. T. Pruter, and L. L. Ronholt. 1964. A study of demersal fishes and fisheries of the northeastern Pacific Ocean. H. R. MacMillan Lectures in Fisheries, Inst. Fish. Univ. Brit. Columbia, Vancouver, B.C., 190 p.

Cailliet, G.M., A.H. Andrews, E.J. Burton, D.L. Watters, D.E. Kline, and L.A. Ferry-Grahan. 2001. Age determination and validation studies of marine fishes; do deep-dwellers live longer? Experimental Gerontology 36: 739-764.

Chitwood, P. E. 1969. Japanese, Soviet, and South Korean fisheries off Alaska, development and history through l966. U.S. Fish Wildl. Serv., Circ. 310, 34 p.

French, R., J. Wall, and V. Wespestad. 1977. The catch of rockfish other than Pacific ocean perch by Japan and the USSR in the Gulf of Alaska. Document submitted to the annual meeting of the INPFC 1977. Northwest and Alaska Fish. Sci. Center, NMFS NOAA, 2725 Montlake Blvd. E. Seattle WA 98112.

Gunderson, D.R. 1997. Trade-off between reproductive effort and adult survival in oviparous and viviparous fishes. Canadian Journal of Fisheries and Aquatic Science 54: 990-998.

Hoenig, J. M. 1983. Empirical use of longevity data to estimate mortality rates. Fish. Bull. 82: 898.903.

Ianelli, J.N., R. Lauth, and L.D. Jacobson, 1994. Status of the thornyhead resource in 1994. Appendix D. *In*: Status of the Pacific coast groundfish fishery through 1994 and recommended acceptable biological catches for 1995. (Vol. 1) Pacific Fishery Management Council. Portland, Oregon.

Ianelli, J.N., and D.H. Ito. 1994. Thornyheads. *In*: Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 1995. Nov. 1994. N. Pac. Fish. Mgt. Council, P.O Box 103136, Anchorage, AK 99510.

Ianelli, J.N., and D.H. Ito. 1995. Thornyheads. *In*: Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 1996. Nov. 1995. N. Pac. Fish. Mgt. Council, P.O Box 103136, Anchorage, AK 99510.

Ianelli, J.N., D.H. Ito, and M. Martin. 1997. Thornyheads. *In*: Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 1998. Nov. 1997. N. Pac. Fish. Mgt. Council, P.O Box 103136, Anchorage, AK 99510.

Ianelli, J.N. and D.H. Ito. 1998. Thornyheads. *In*: Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 1999. Nov. 1998. N. Pac. Fish. Mgt. Council, P.O Box 103136, Anchorage, AK 99510.

Jacobson, L. D. 1990. Thornyheads--stock assessment for 1990. Appendix D. *In*: Status of the pacific coast groundfish fishery through 1990 and recommended acceptable biological catches for 1991. Pacific Fishery Management Council. Portland, Oregon.

Kastelle, C.R., D.K. Kimura, and S.R. Jay. 2000. Using 210Pb/226Ra disequilibrium to validate conventional ages in Scorpaenids (genera Sebastes and Sebastolobus). Fisheries Research 46: 299-312.

Kline, D.E. 1996. Radiochemical age verification for two deep-sea rockfishes Sebastolobus altivelis and S. alascanus. M.S. Thesis, San Jose State University, San Jose CA, 124 pp.

Methot, R.D. 1990. Synthesis model: An adaptable framework for analysis of diverse stock assessment data. Int. North Pac. Fish. Comm. Bull. 50: 259-289.

Miller, P. P. 1985. Life history study of the shortspine thornyhead, *Sebastolobus alascanus*, at Cape Ommaney, south-eastern Alaska. M.S. Thesis, Univ. Alaska, Fairbanks, AK, 61 p.

Pearson, K.E., and D.R. Gunderson, in review. Reproductive biology and ecology of shortspine thornyhead rockfish (Sebastolobus alascanus) and longspine thornyhead rockfish (S. Altivelis) from the northeastern Pacific Ocean. Unpubl. manuscr., 33 pp.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. No. 191, 382 p.

Sasaki, T., and K. Teshima. 1988. Data report on abundance indices of flatfishes, rockfishes, shortspine thornyhead and grenadiers based on the results from Japan-U.S. joint longline surveys, 1979-1987. Unpubl. manuscr., 26 p. (Document submitted at the U.S.-Japan Groundfish Workshop,1988.) Far Seas Fisheries Research Laboratory, Shimizu, Japan.

Sigler, M. and H. Zenger, Jr. 1994. Relative abundance of Gulf of Alaska sablefish and other groundfish based on the domestic longline survey, 1989. NOAA Tech. Memo NMFS-AFSC-40. 79 p.

Wakabayashi, K., R.G. Bakkala, and M.S. Alton. 1985. Methods of the U.S.-Japan demersal trawl surveys. P. 7-29. *In* R.G. Bakkala and K. Wakabayashi (eds.), Results of cooperative U.S.-Japan groundfish investigations in the Bering Sea during May-August 1979. Int. North Pac. Fish. Comm., Bull. 44.

Wall, J., R. French, and R. Nelson Jr. 1979. Observations of foreign fishing fleets in the Gulf of Alaska, 1978. Document submitted to the annual meeting of the INPFC 1979. Northwest and Alaska Fish. Sci. Center, NMFS NOAA, 2725 Montlake Blvd. E. Seattle WA 98112.

Wall, J., R. French, and R. Nelson Jr. 1980. Observations of foreign fishing fleets in the Gulf of Alaska, 1979. (Document submitted to the annual meeting of the INPFC, Anchorage, AK. Sept. 1979.) 78 p. Northwest and Alaska Fish. Sci. Center, NMFS NOAA, 2725 Montlake Blvd. E. Seattle WA 98112.

Wall, J., R. French, and R. Nelson Jr. 1981. Observations of foreign fishing fleets in the Gulf of Alaska, 1980. (Document submitted to the annual meeting of the INPFC, Vancouver, B.C., Canada. Sept. 1981.) Northwest and Alaska Fish. Sci. Center, NMFS NOAA, 2725 Montlake Blvd. E. Seattle WA 98112.

Wall, J., R. French, and R. Nelson Jr. 1981. Observations of foreign fishing fleets in the Gulf of Alaska, 1980. (Document submitted to the annual meeting of the INPFC, Vancouver, B.C., Canada. Sept. 1981.) Northwest and Alaska Fish. Sci. Center, NMFS NOAA, 2725 Montlake Blvd. E. Seattle WA 98112.

Wall, J., R. French, R. Nelson Jr., and D. Hennick. 1978. Observations of foreign fishing fleets in the Gulf of Alaska, 1977. Document submitted to the annual meeting of the INPFC 1978. Northwest and Alaska Fish. Sci. Center, NMFS NOAA, 2725 Montlake Blvd. E. Seattle WA 98112.

Wall, J., R. Nelson Jr, and J. Berger. 1982. Observations of foreign fishing fleets in the Gulf of Alaska, 1981. (Document submitted to the annual meeting of the INPFC, Tokyo, Japan. October. 1982.) Northwest and Alaska Fish. Sci. Center, NMFS NOAA, 2725 Montlake Blvd. E. Seattle WA 98112.

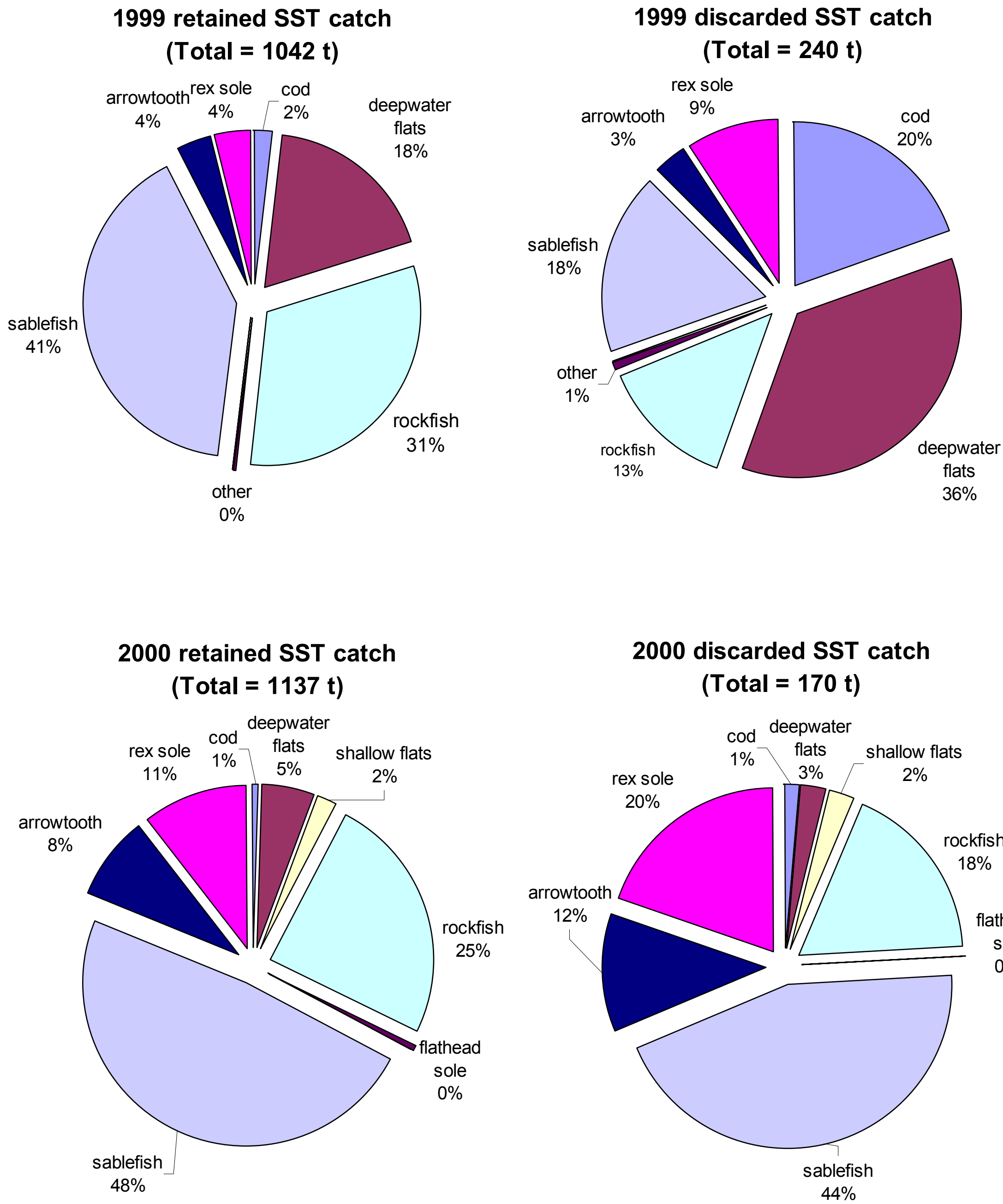


Figure 9.1. Proportion retained and discarded shortspine thornyhead by target fishery in 1999-2000. *Source: NMFS Alaska Fisheries Science Center and Regional Office blend data.*

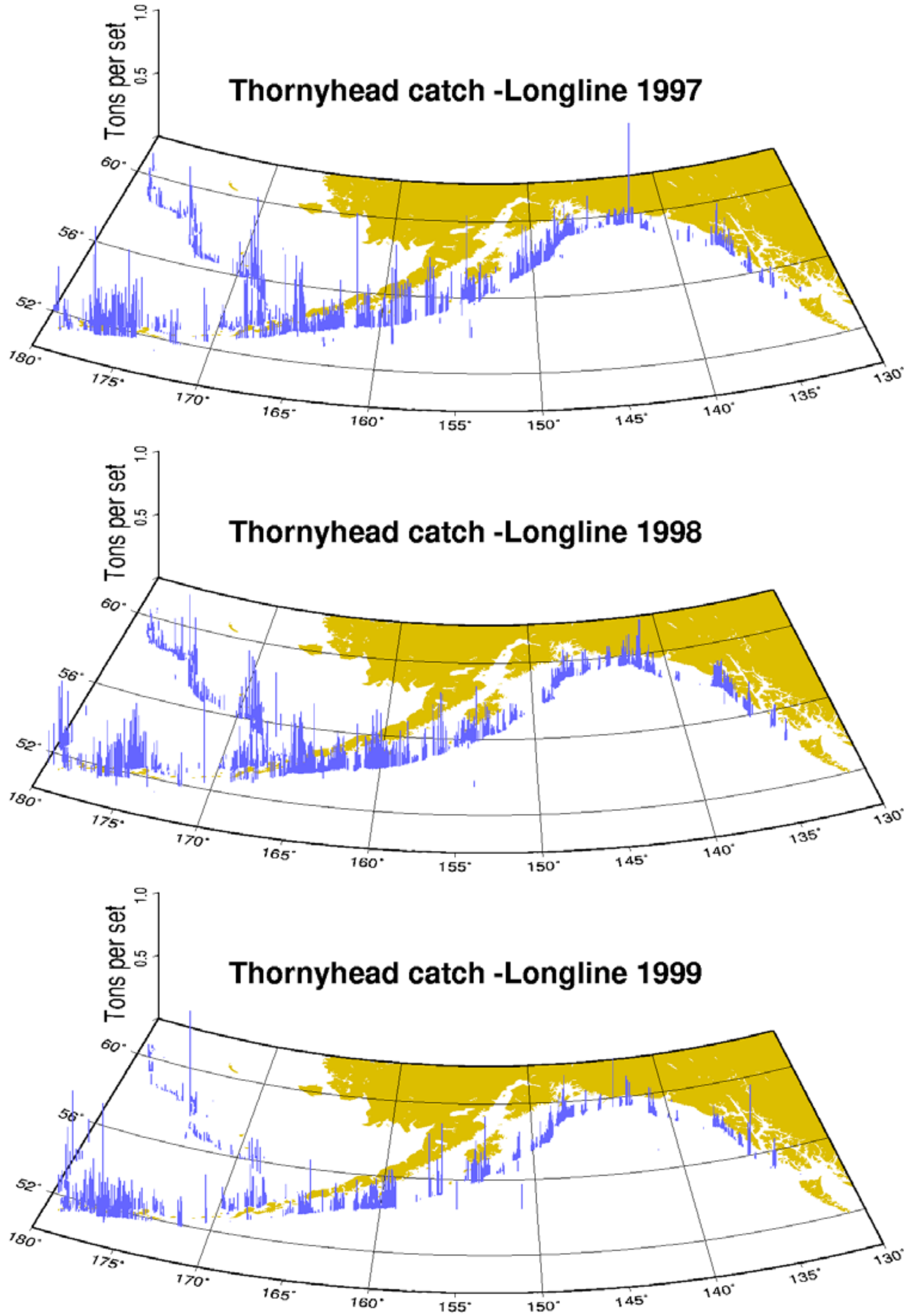


Figure 9.2. Distribution of thornyhead catches by commercial longline gear, 1997-1999.

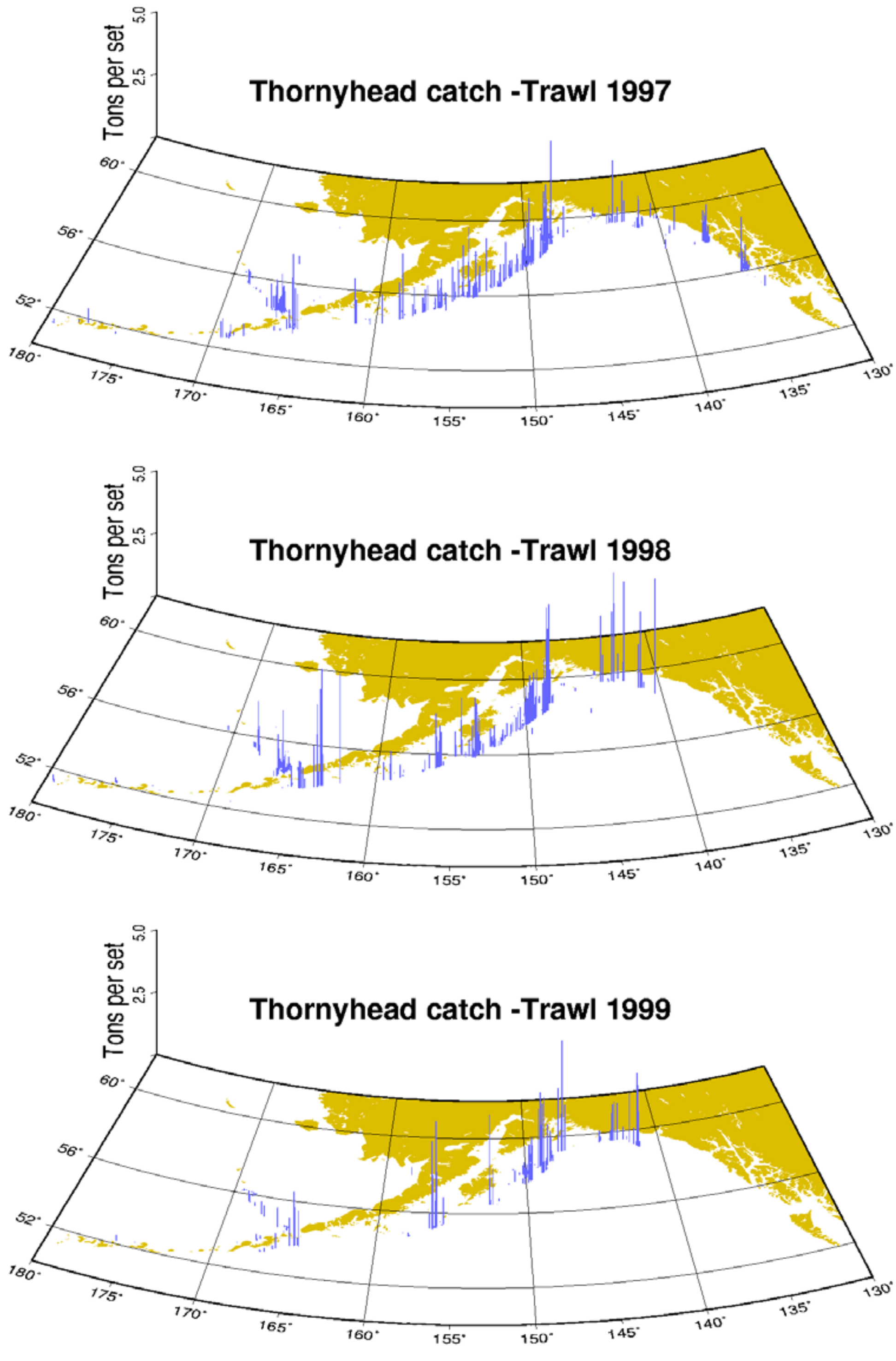
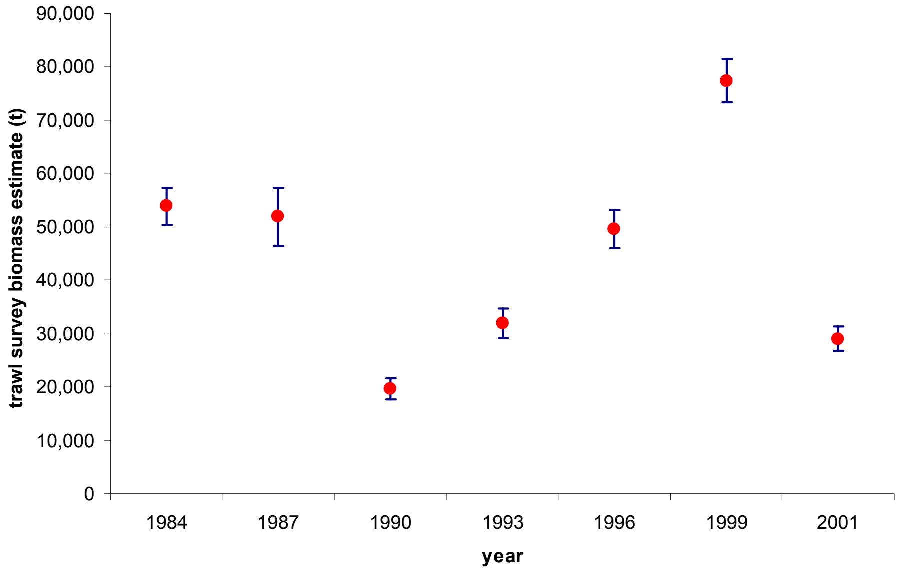


Figure 9.3. Distribution of thornyhead catches by commercial trawl gear, 1997-1999.



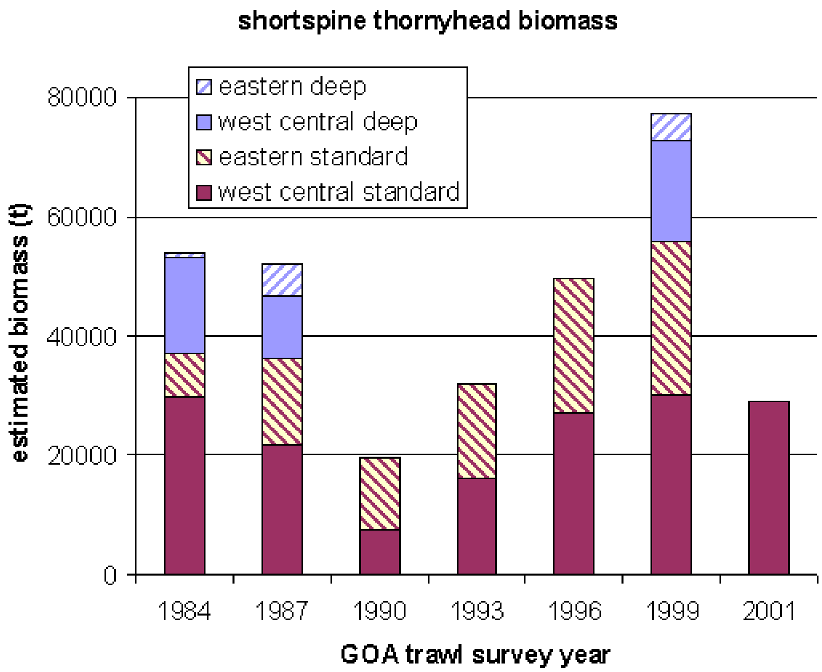


Figure 9.4. Shortspine thornyhead biomass estimates (with standard errors) from the NMFS triennial trawl survey (upper panel). Biomass estimates by survey depth strata and region (lower). Note that the 1990, 1993, and 1996 surveys did not extend to deep water (>500m), consequently, a significant proportion of the stock may not have been sampled. In 2001, neither deep water stations nor the eastern Gulf were surveyed; therefore, significant portions of the stock were not sampled.

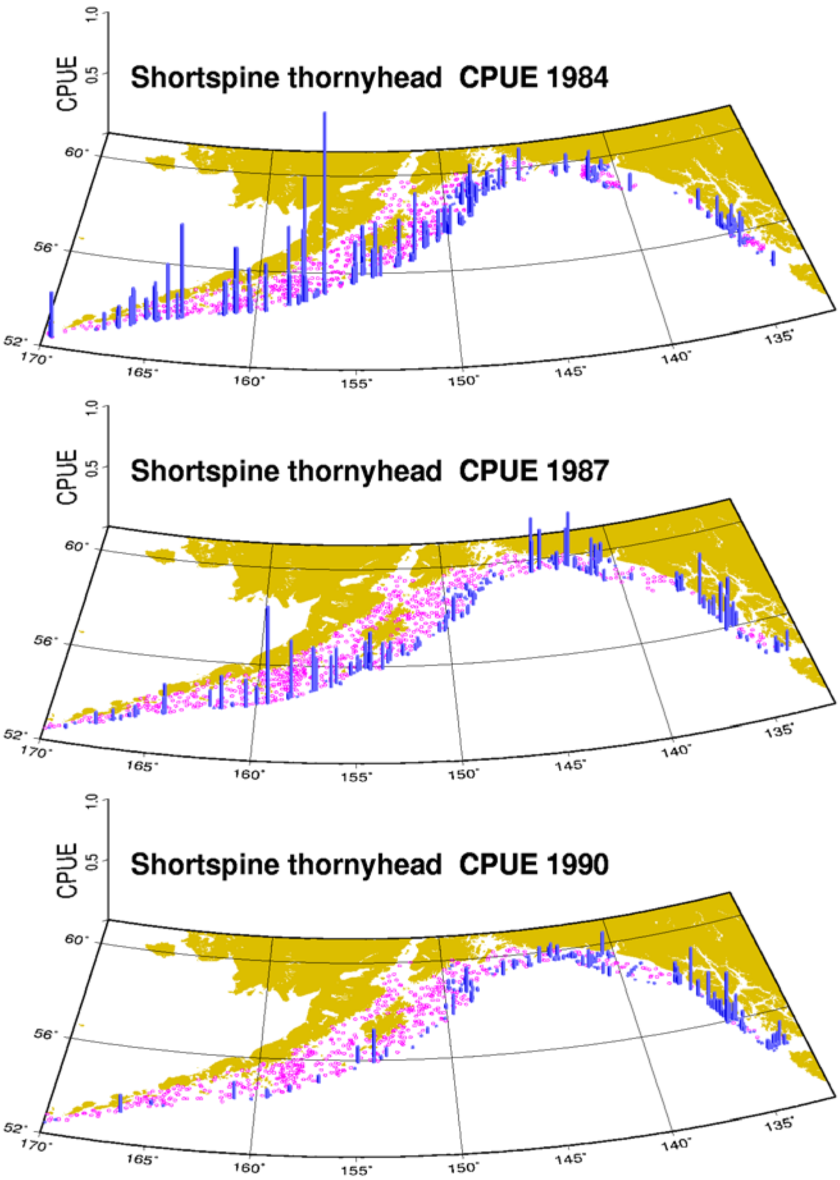


Figure 9.5. Distribution of thornyhead CPUE from recent triennial trawl surveys. Height of vertical bars is proportional to CPUE by weight. Circles represent stations where no shortspine thornyheads were captured.

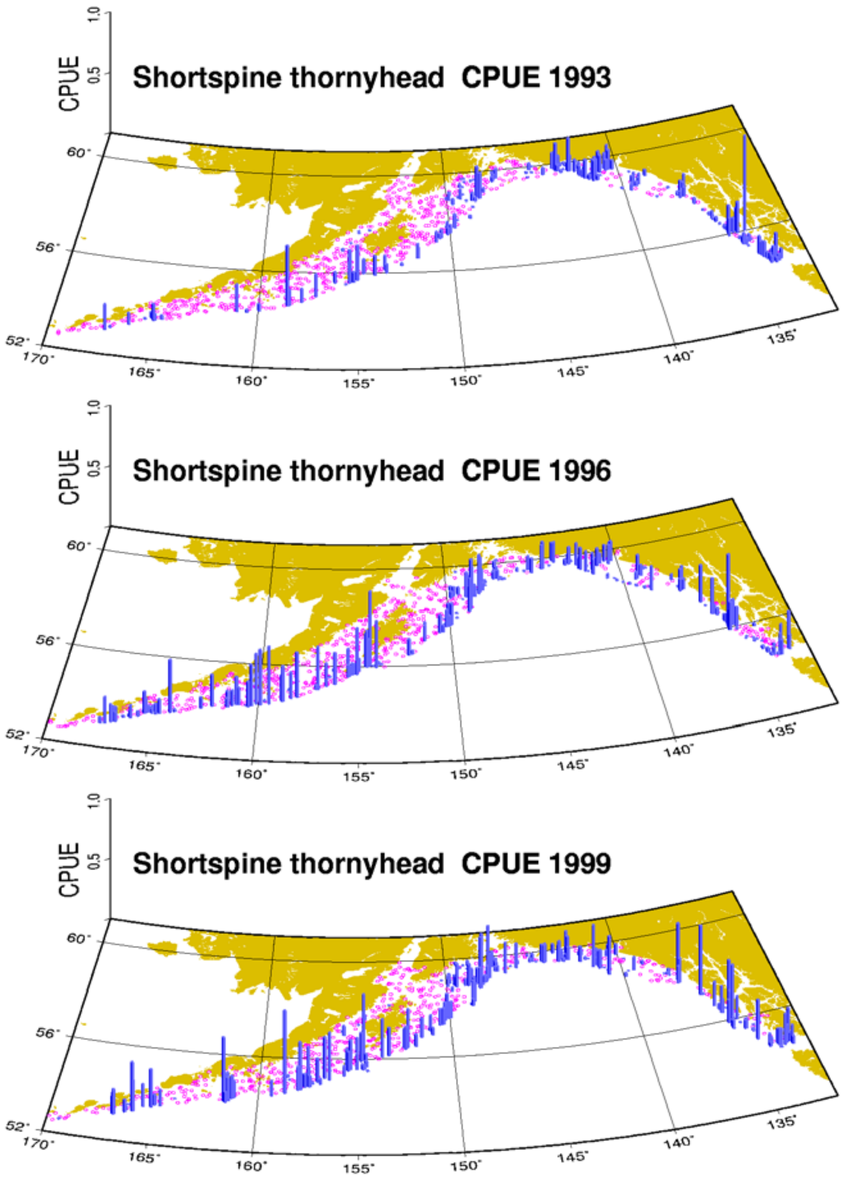


Figure 9.5 (cont'd). Distribution of thornyhead CPUE from recent triennial trawl surveys. Height of vertical bars is proportional to CPUE by weight. Circles represent stations where no shortspine thornyheads were captured.

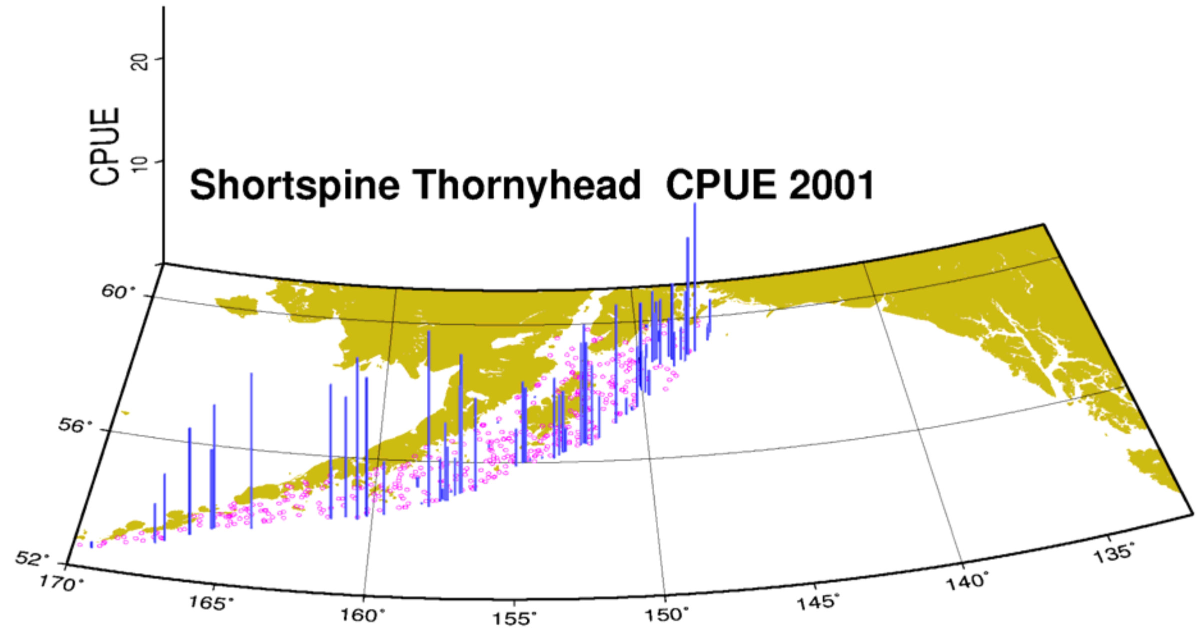


Figure 9.5 (cont'd). Distribution of thornyhead CPUE from recent triennial trawl surveys. Height of vertical bars is proportional to CPUE by weight. Circles represent stations where no shortspine thornyheads were captured. The eastern Gulf of Alaska and stations deeper than 500 m were not sampled during the 2001 bottom trawl survey.

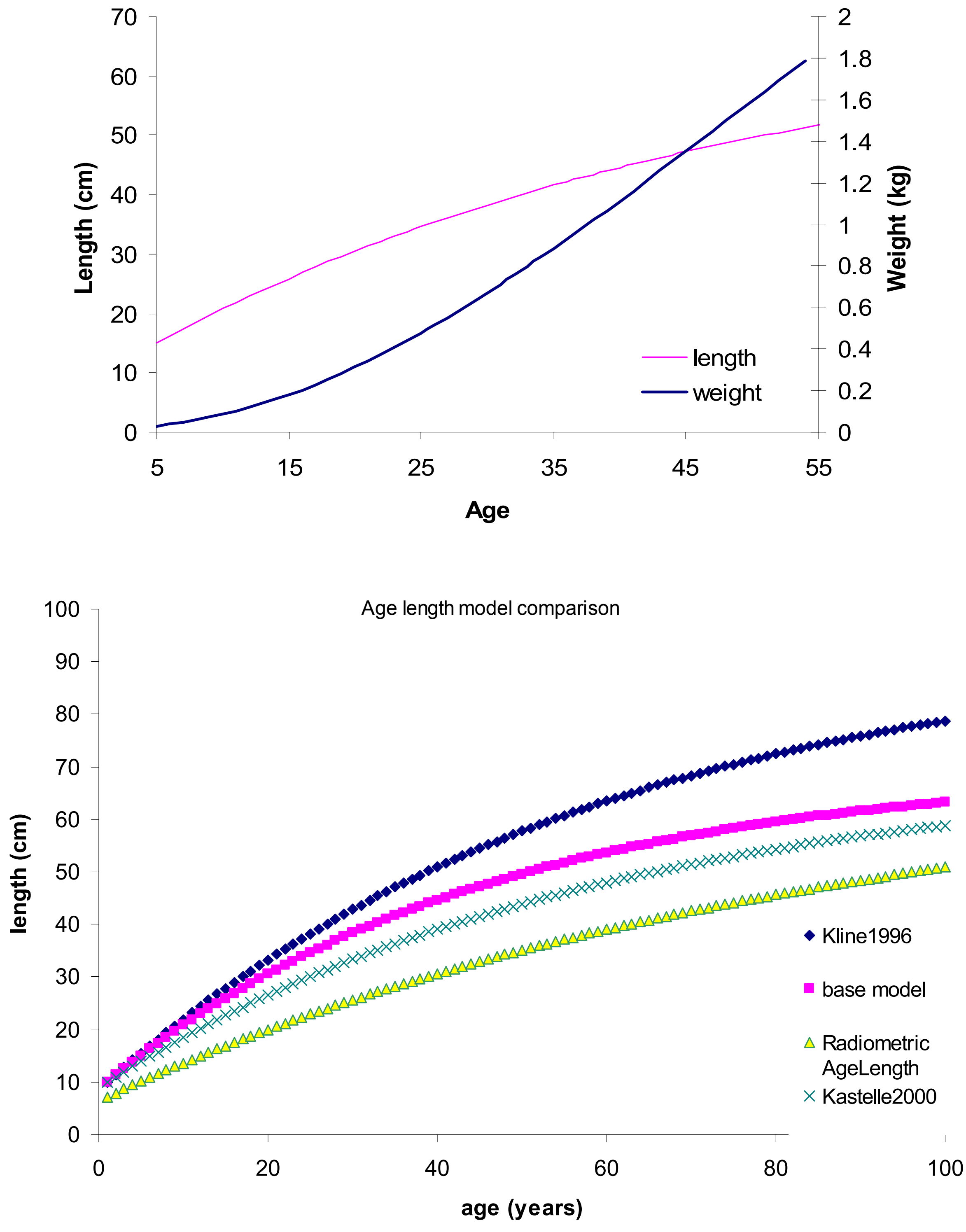


Figure 9.6. (upper) Assumed average length and weight at age for Gulf of Alaska shortspine thornyheads. (lower) Alternative growth models tested.

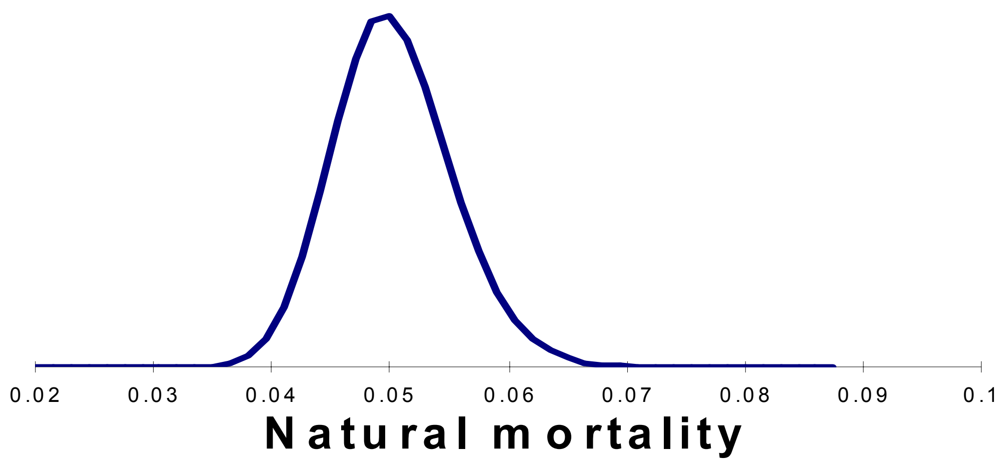


Figure 9.7. Prior distribution assumed for natural mortality of thornyheads (base model and alternative AgeLength models).

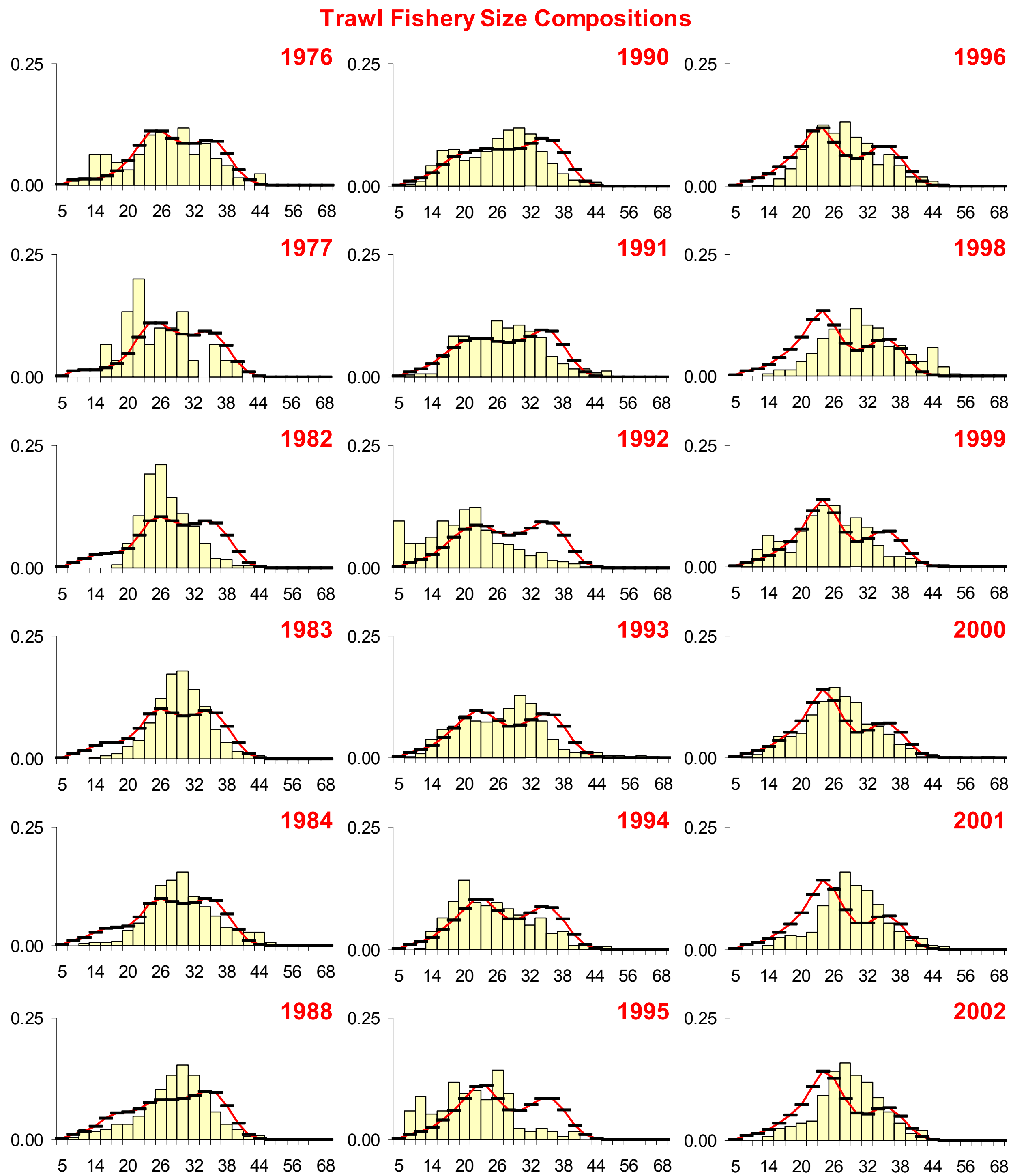


Figure 9.8. Radiometric AgeLength Model fits to the trawl shortspine thornyheads fishery size composition data.

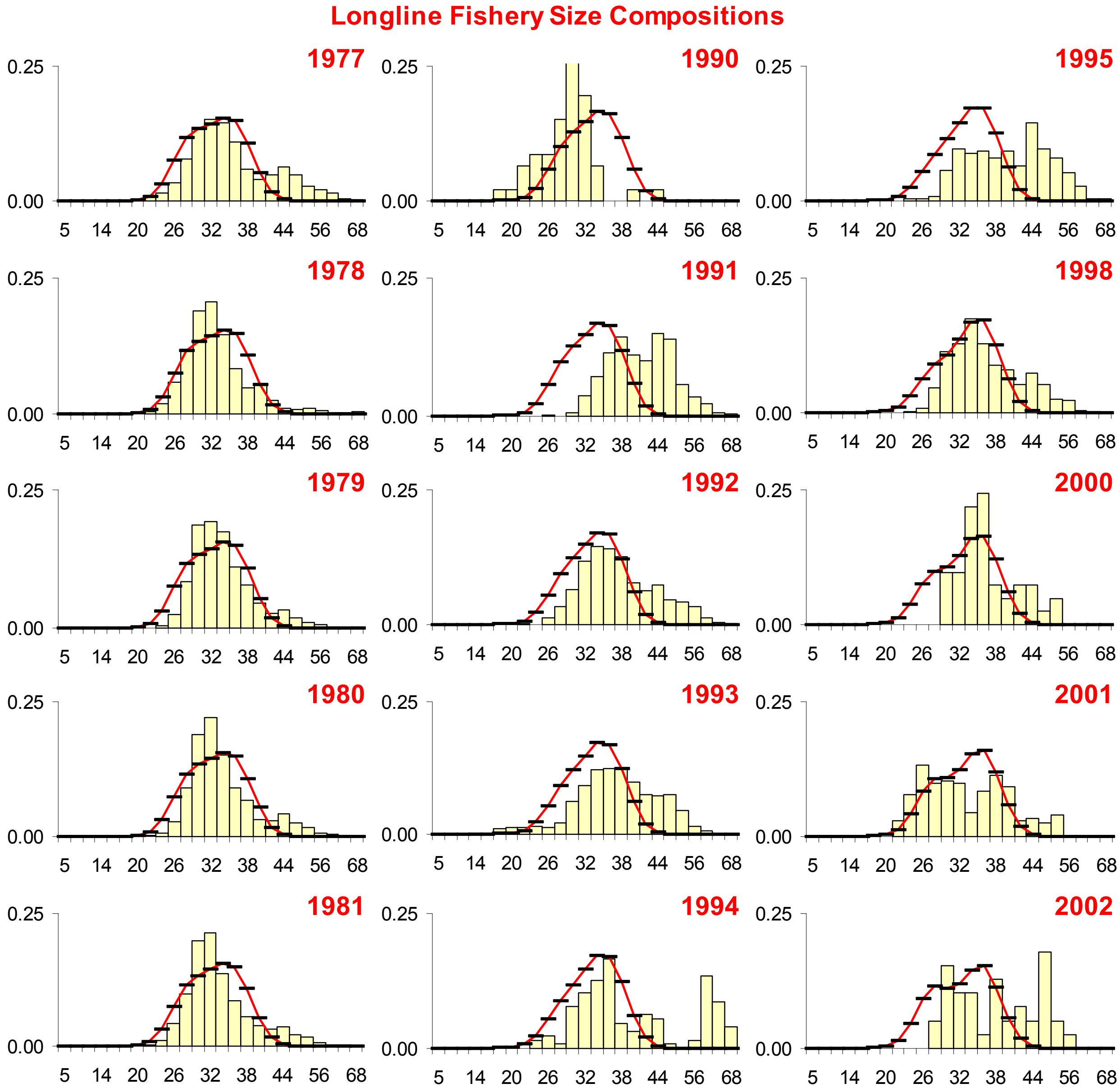


Figure 9.8. (Cont'd) Radiometric AgeLength Model fits to the longline shortspine thornyheads fishery size composition data.

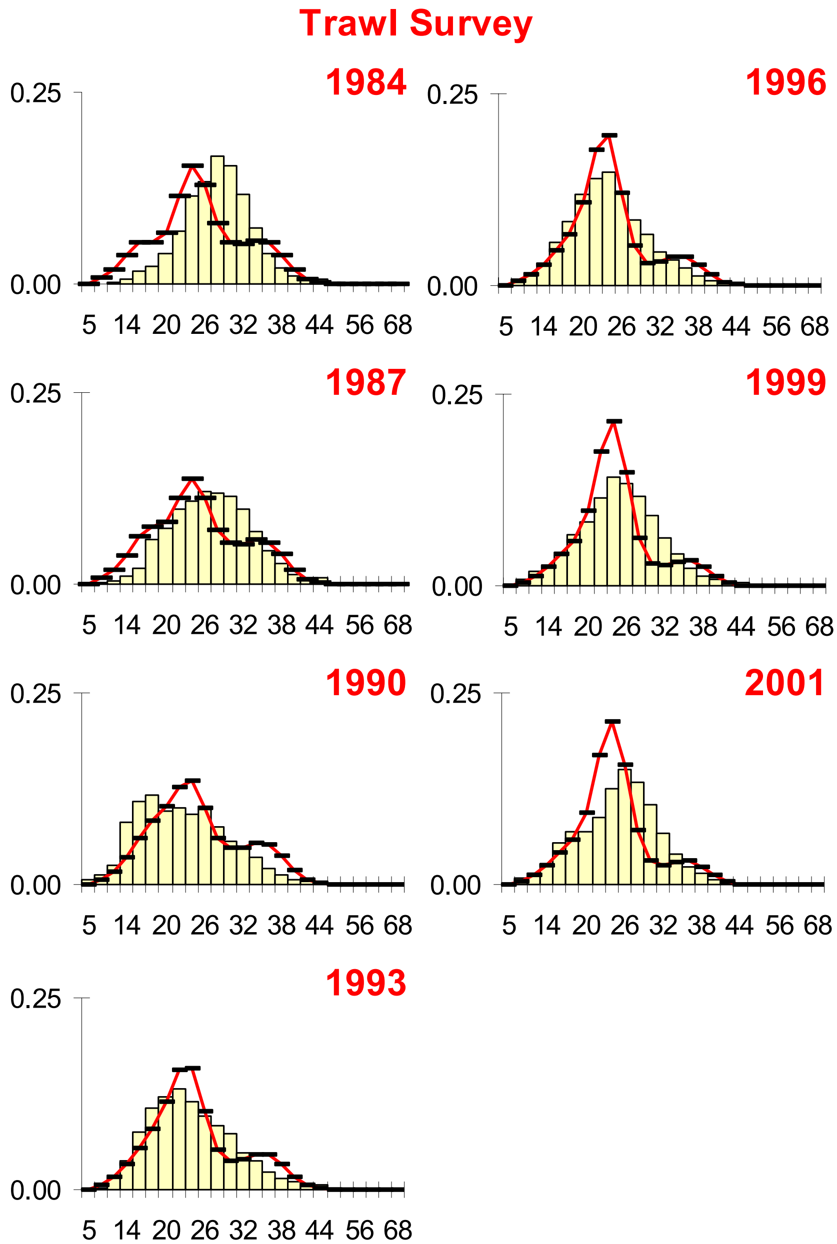


Figure 9.8. (Cont'd) Radiometric AgeLength Model fits to the trawl survey size composition data.

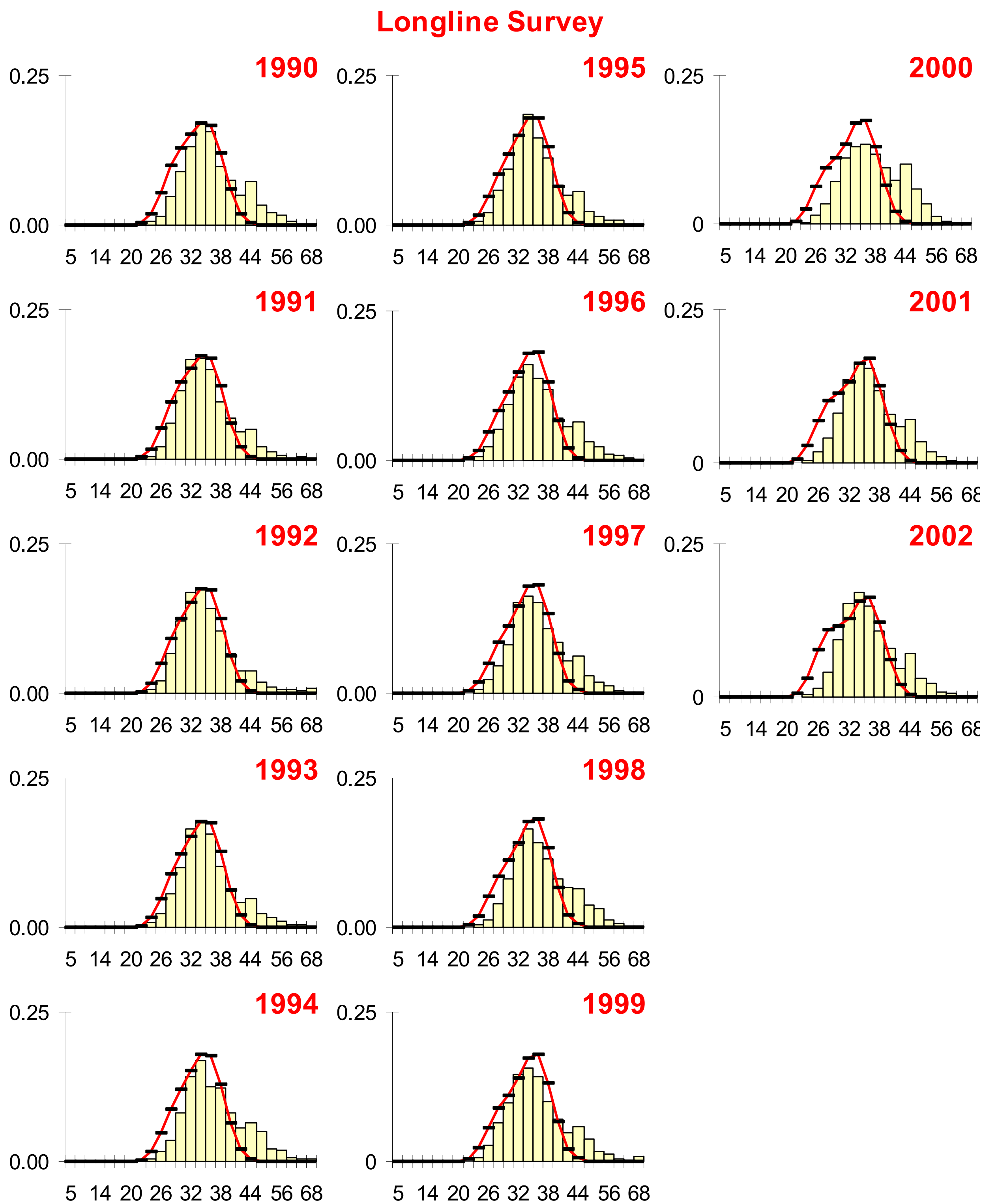


Figure 9.8. (Cont'd) Radiometric AgeLength Model fits to the longline survey shortspine thornyheads size composition data.

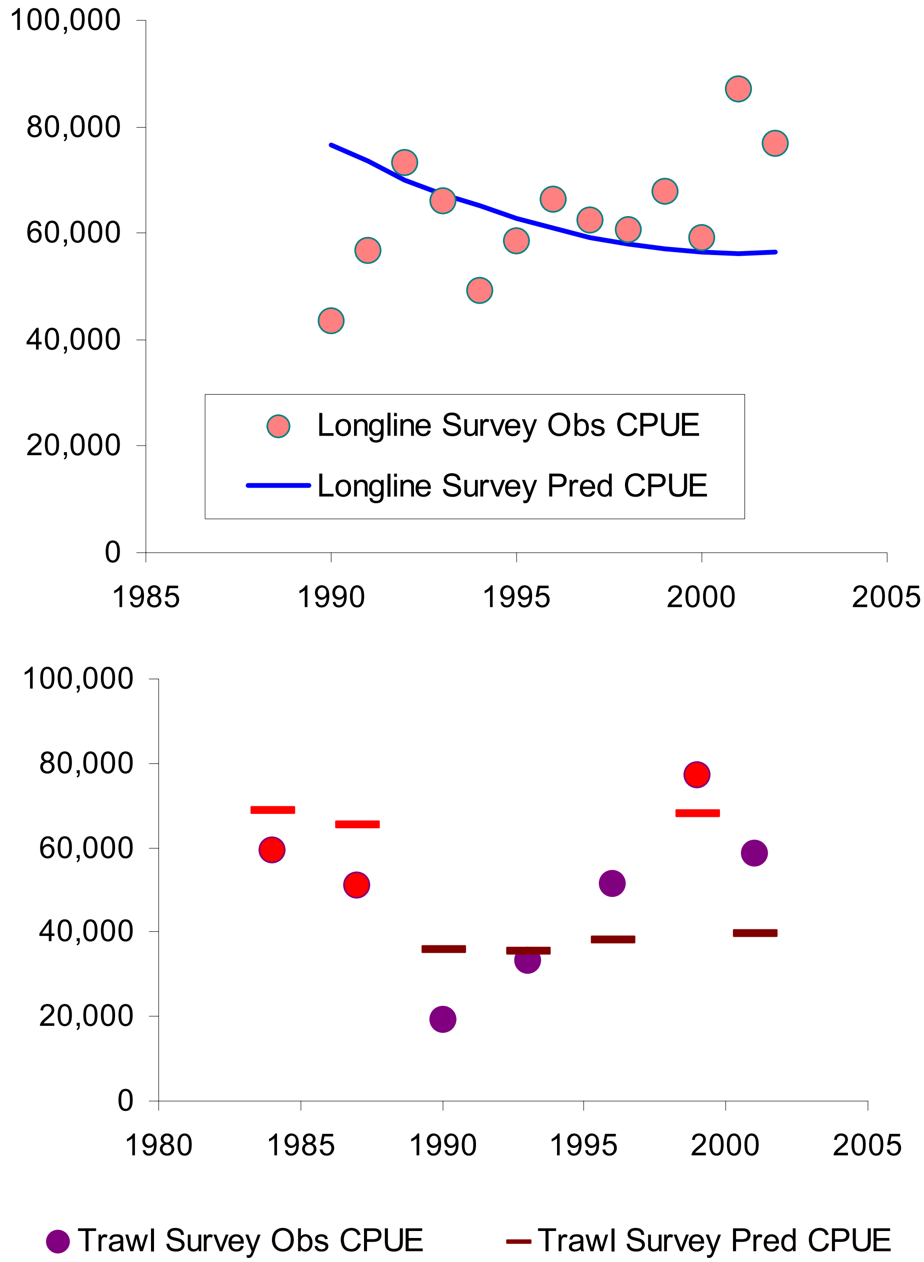


Figure 9.9. Radiometric AgeLength Model fits to the relative abundance index from the longline surveys (RPN, top panel) and the triennial trawl surveys (bottom panel) for shortspine thornyheads. Note that the triennial survey was modeled with two catchability terms to reflect the change in distribution covered by the survey after 1989.

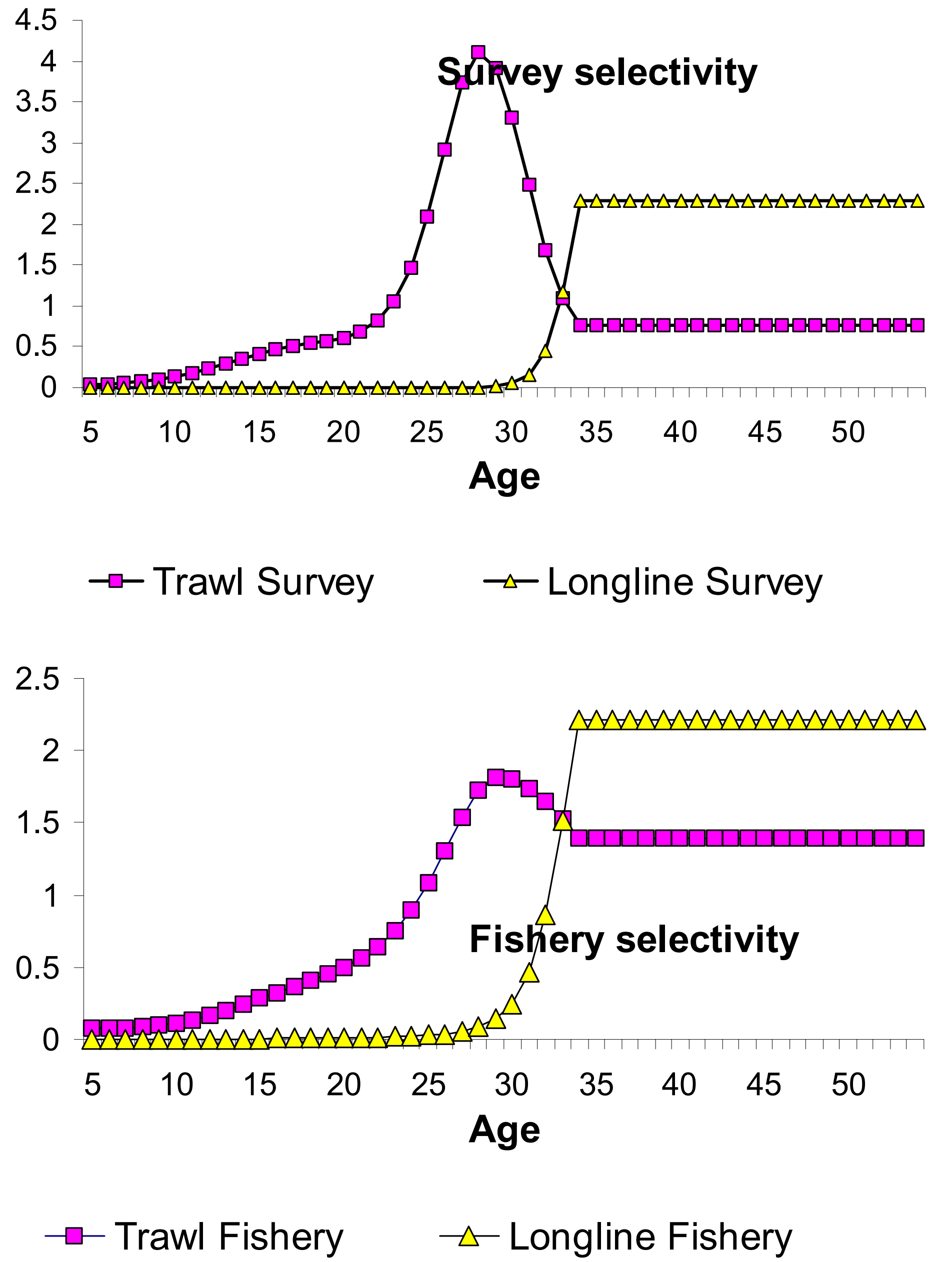


Figure 9.10. Selectivity of shortspine thornyheads estimated by the Radiometric AgeLength model for the surveys (upper panel) and fisheries (lower panel).

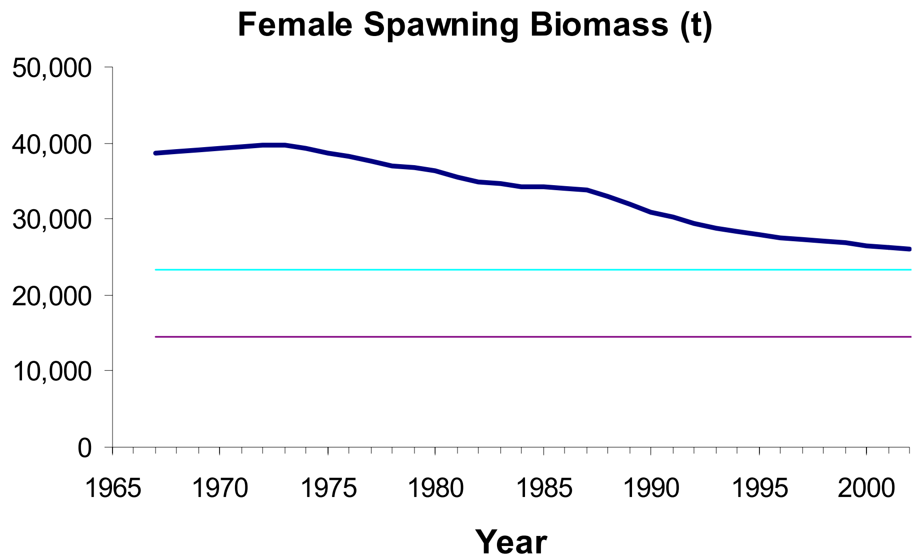


Figure 9.11. Radiometric AgeLength model estimated female spawner biomass trajectory (heavy line) for shortspine thornyheads in the Gulf of Alaska. Upper straight line is unfished biomass, lower straight line is $B_{35\%}$ (as defined from average year-class estimates since 1977).

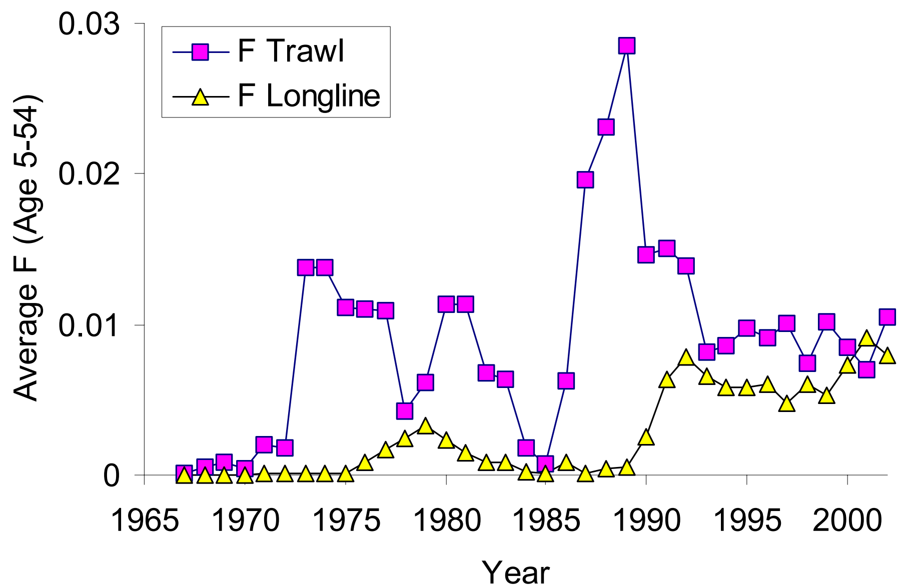


Figure 9.12. Radiometric AgeLength model average (over ages 5-54) fishing mortality rate by gear type on shortspine thornyheads in the Gulf of Alaska, 1967-2002.

Figure 9.13. The stock-recruitment plot (upper panel) and time series of recruitment strengths (lower panel) from the Radiometric AgeLength model for shortspine thornyheads in the Gulf of Alaska.

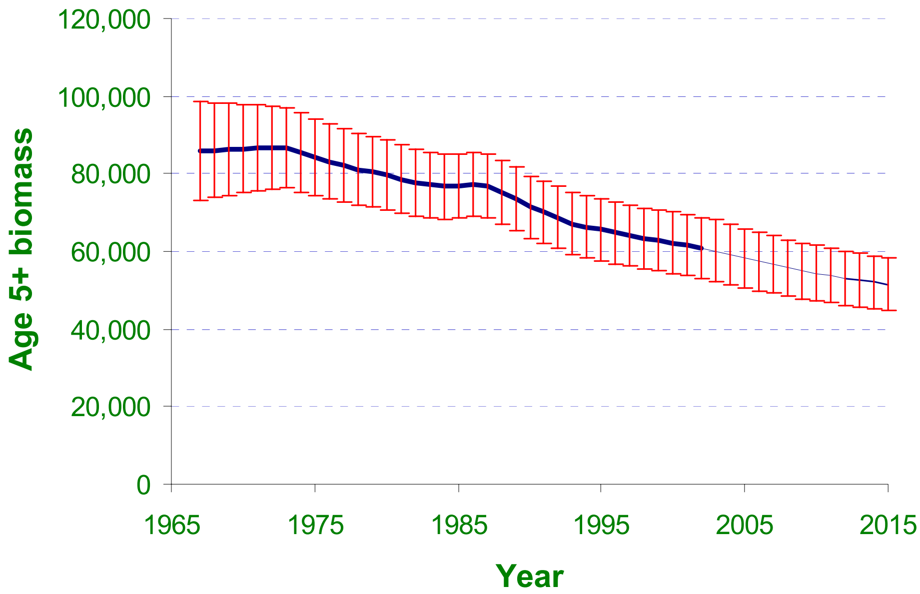


Figure 9.14. Radiometric AgeLength model historical and projected shortspine thornyhead age 5+ biomass with 2 standard deviations. Note that future projections are based on an assumed $F_{40\%}$ fishing mortality rate.

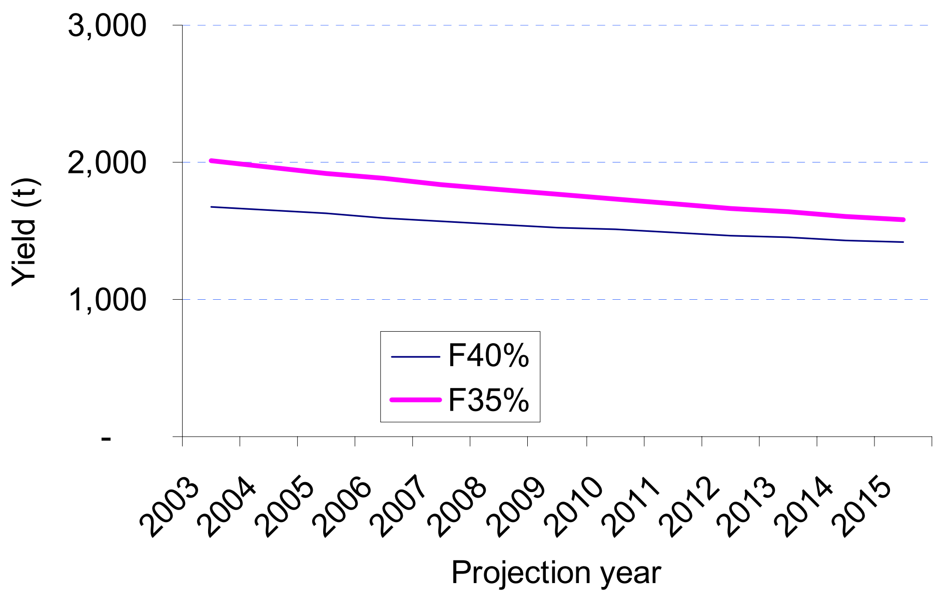


Figure 9.15. Radiometric AgeLength model projected future yield of shortspine thornyheads under alternative SPR fishing mortality rates.

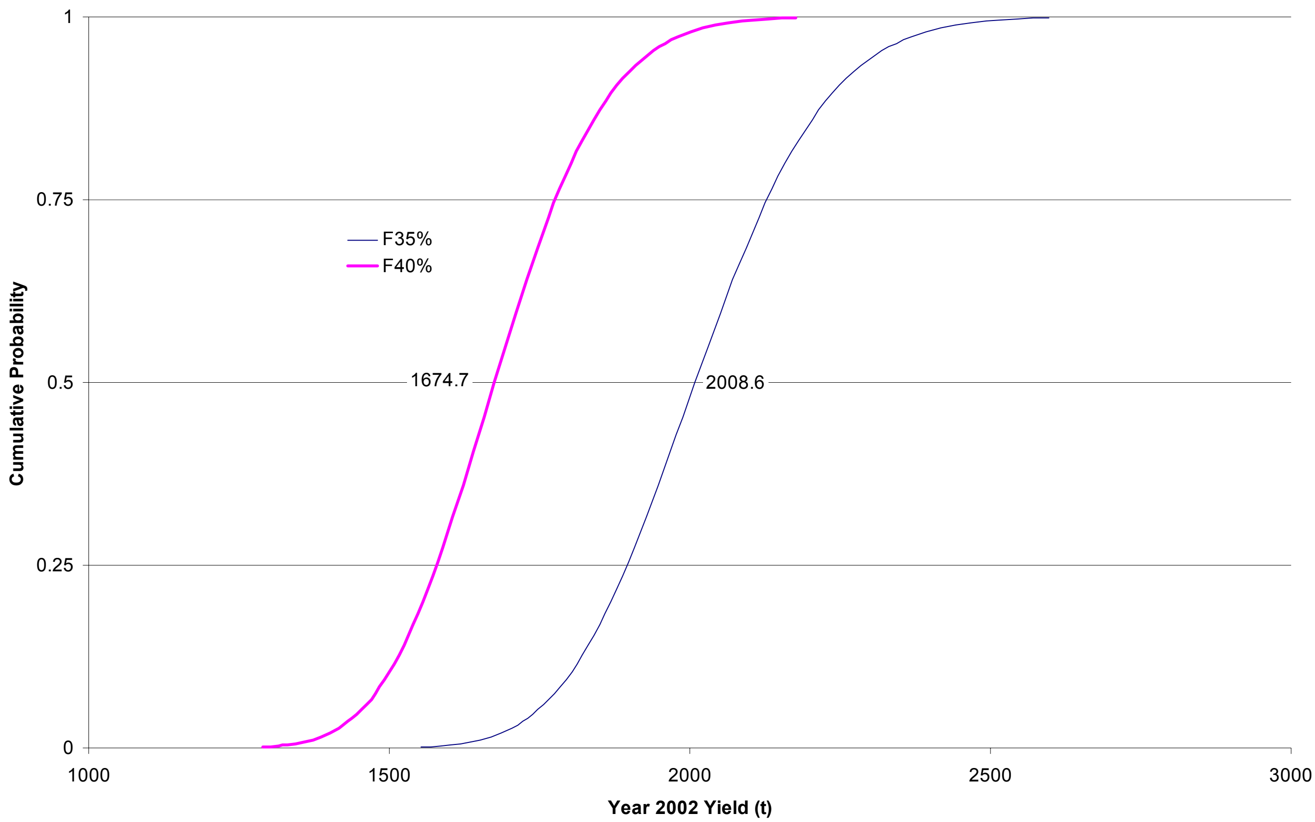


Figure 9.16. Radiometric AgeLength model projected 2003 shortspine thornyhead yield under alternative SPR harvest rates. The cumulative probability reflects uncertainty in the current stock size in addition to uncertainty in estimating the SPR rates themselves.

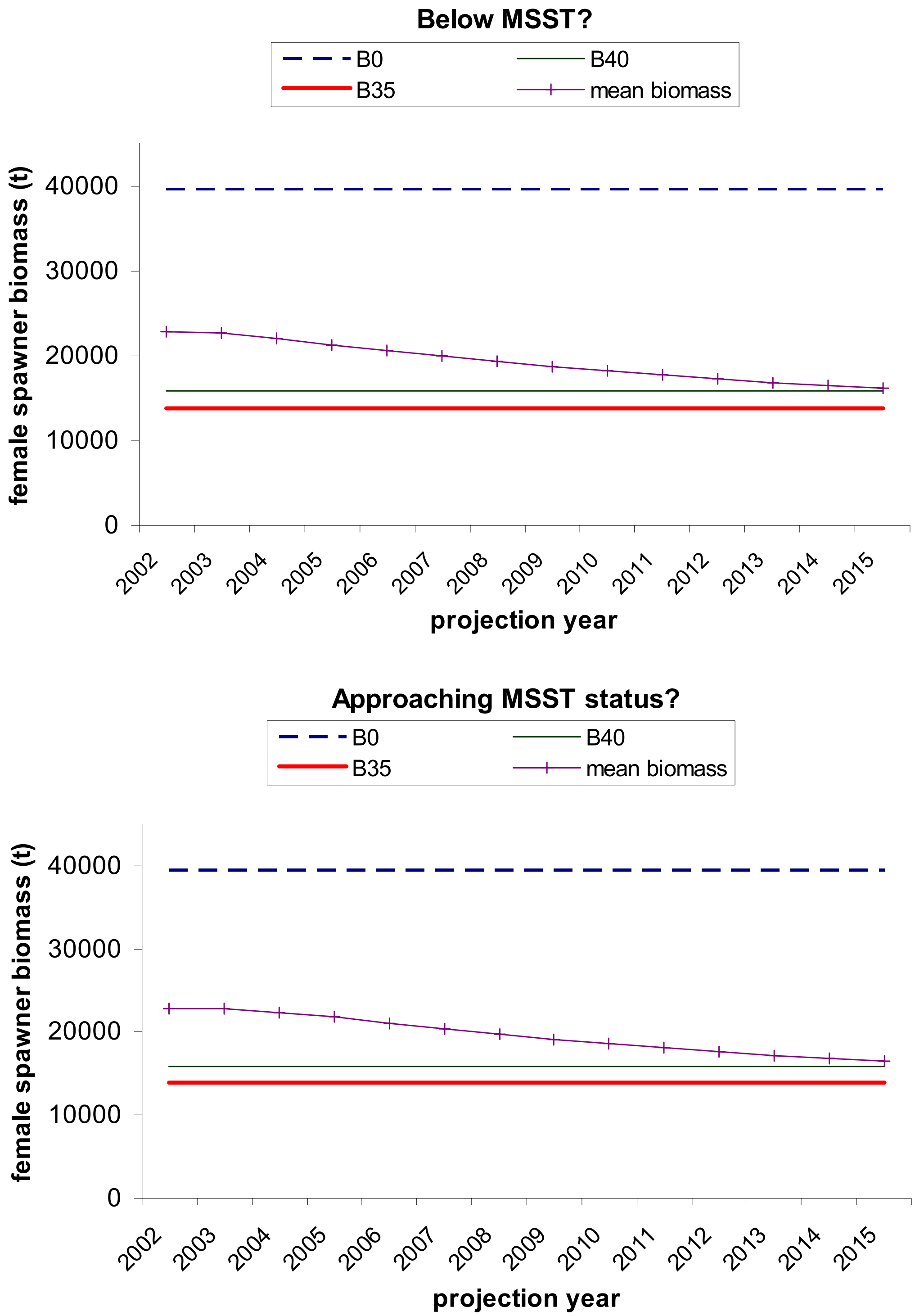


Figure 9.17. Base model projected shortspine thornyhead female spawning biomass under two scenarios. Top panel (scenario 6 in text): In all future years, F is set equal to F_{OFL}. Bottom pane (scenario 7 in text): In 2003 and 2004, F is set equal to *max* F_{ABC}, and in all subsequent years, F is set equal to F_{OFL}.